INDEX

TO THE

EXECUTIVE DOCUMENTS

OF THE

HOUSE OF REPRESENTATIVES

FOR THE

THIRD SESSION OF THE FORTY-FIFTH CONGRESS,

1878-'79.

IN 18 VOLUMES.

VOLUME VI.—REPORT OF THE CHIEF OF ORDNANCE.

WASHINGTON:
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1879.

INDEX TO HOUSE EXECUTIVE DOCUMENTS.

CONTENTS OF THE VOLUMES.

INDEX TO THE DOCUMENTS.

45TH CONGRESS, 3d Session. } HOUSE OF REPRESENTATIVES. { Ex. Doc. 1, Part 2.

REPORT

OF THE

SECRETARY OF WAR;

BEING PART OF

THE MESSAGE AND DOCUMENTS

COMMUNICATED TO THE

TWO HOUSES OF CONGRESS

AT THE

BEGINNING OF THE THIRD SESSION OF THE FORTY-FIFTH CONGRESS.

VOLUME III.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1878.

REPORT

OF THE

CHIEF OF ORDNANCE.

REPORT OF THE CHIEF OF ORDNANCE.

WAR DEPARTMENT, ORDNANCE OFFICE,
Washington, October 10, 1878.

The Hon. SECRETARY OF WAR:

SIR: I have the honor to submit the following report of the principal operations of the Ordnance Department during the fiscal year ended June 30, 1878, with such remarks and recommendations as the interests of this branch of the military service seem to require.

The fiscal resources and expenditures of the department during the year were as follows, viz:

Amount in the Treasury to the credit of appropriations on June 30, 1877	$25,356 79
Amount in the Treasury not reported to the credit of appropriations on June 30, 1877	3,919 99
Amount in government depositories to the credit of disbursing-officers and others on June 30, 1877	194,236 88
Amount of appropriations for the service of the fiscal year ended June 30, 1878	1,136,004 48
Amount refunded to ordnance appropriations in settling accounts during the fiscal year ended June 30, 1878	6,393 25
Gross amount received during the fiscal year ended June 30, 1878, from sales to officers; from rents; from collections from troops on account of losses of, or damage to, ordnance stores; from Chicago, Rock Island and Pacific Railroad Company; from exchange of powder; from sales of condemned stores; and from all other sources not before mentioned	115,900 16
Total	1,481,811 55
Amount of expenditures during the fiscal year ended June 30, 1878, including expenses attending sales of condemned stores, exchange of powder, etc	1,188,580 82
Amount in the Treasury not reported to the credit of the appropriations on June 30, 1877, since covered in during year ended June 30, 1878, as proceeds of sales	120 75
Amount deposited in the Treasury during the fiscal year ended June 30, 1878, as proceeds of sales of government property	12,057 32
Amount lapsed in the Treasury from the appropriation "Ordnance material" under act of March 3, 1875, during the fiscal year ended June 30, 1878	3 21
Amount transferred from ordnance appropriations in settling accounts during the fiscal year ended June 30, 1878	476 82
Amount in government depositories to the credit of disbursing-officers and others on June 30, 1878	161,134 72
Amount in the Treasury not reported to the credit of appropriations on June 30, 1878	19,034 95
Amount in the Treasury to the credit of appropriations on June 30, 1878	100,402 96
Total	1,481,811 55

The stations and duties of the officers and storekeepers of the department on the 1st of October, 1878, were as follows, viz: *2 at the Ordnance Office, War Department; 35 at the arsenals; 8 at the ordnance agency, on the ordnance board and foundery duty; 9 at the headquarters of military divisions, departments, and ordnance depots; 3 at the Military Academy; 2 on detached duty; 4 on leave of absence (3 sick).

Since my last report 3 officers have died and 1 has been placed on the retired list, while 2 have entered the corps from the line, under the provisions of existing law, after passing a competitive examination.

ARSENALS AND DEPOTS.

The duties at the several arsenals and the armory during the past year have been performed in a satisfactory manner, and expenditures have been judiciously and economically made. The continuation of the erection of buildings at the Rock Island Arsenal has been prosecuted satisfactorily to the extent of the appropriation, under the supervision and control of Major Flagler, commanding. The manufacture of leather and carriage work at the Watervliet Arsenal, under Colonel Hagner, and of ammunition at the Frankford Arsenal, under Major Whittemore, have sustained their well-deserved reputation. The general service of supplying the different branches of the military establishment has been performed by the officers of the department in their usual commendable manner.

Upon the recommendation of this office, the law for the establishment of ordnance depots (section 1165 Revised Statutes) has been vitalized, and, under the direction of the Secretary of War, depots have been established at Fort Abraham Lincoln, Fort Leavenworth, Fort Yuma, and Cheyenne. The principal object of these depots is to place a reserve supply of stores in a convenient locality, under the immediate control and command of the department commander, for the supply of his own troops, and it is believed that through such an instrumentality the supplying of the Army in distant portions of the country can be done more expeditiously and perfectly.

SMALL-ARMS.

Only $100,000 were appropriated for the manufacture of small-arms at the National Armory during the last fiscal year. On the 1st instant there were in store as a reserve supply 15,900 rifles, 6,685 carbines, total, 22,585 arms of the latest model. I have submitted an estimate of $900,000 for the manufacture of arms during the next fiscal year. The necessity for an accumulation of arms of the latest pattern has been so often discussed, has received such practical application on the part of other countries, that a further reference to it in this report would be a work of supererogation. The moral effect of a large supply of arms in

* In this statement some officers are counted twice, owing to the nature of their duties. For a detailed statement see Appendix G.

readiness for use is always entirely disregarded in the discussion of the subject. To be prepared for immediate hostilities is a quiet power, which must enter largely as an important factor in the determination of international questions that may or may not lead to war, and, as such power, it is worth all the money expended in its production. The argument so frequently used, that the gun of to-day will probably be superseded by a superior invention a few years hence, and the expense of to-day be money thrown away, might be used with equal force and pertinence respecting any article of manufacture whatever. But the present approved arm cannot be rendered worthless by the introduction of an improved weapon, because as long as small-arms are fired from the shoulder and the propelling force is gunpowder, the caliber of gun and dimensions of cartridge, now regulation, will not be changed, and the improvement will only consist in more rapid manipulation and increased rapidity of fire. As a case exactly in point, the Board on Magazine Guns has recommended a gun for trial in the hands of troops that is an improvement on the present Springfield arm only in its ability to empty its magazine of cartridges in one-half the time that the same number of shots could be fired by the latter. Used as an ordinary breech-loader, its advantages, if any, are not material or worth consideration, and yet its use as a single breech-loader will be its normal condition, the increased rapidity of the magazine-feeding being reserved for great emergencies. Such a gun, if approved and adopted, in a few years will not render the Springfields that may be on hand worthless. I therefore hope that Congress may be liberal in its appropriation.

As a military weapon the Springfield rifle continues to hold its own for close shooting, and its recent record at Creedmoor is not an unexpected sequence to its success in the "inter-State military" match of last year. At the meeting at Creedmoor last month, in the Army and Navy Journal match, the U. S. Engineer Battalion team, armed with the Springfield rifle, took the first prize, valued at $750, distance fired 500 yards; and in the short-range match, distance 200 and 300 yards, the first prize was awarded to the Springfield Armory Rifle Club team—fifteen teams competing.

Magazine-gun.—The act making appropriations for the support of the Army for the year ending June 30, 1878, and for other purposes, approved November 21, 1877, contains this provision:

> For manufacture of arms at the National Armory, one hundred thousand dollars; and should a board of ordnance officers, appointed by the Secretary of War, recommend a magazine-gun for the military service, the Secretary of War is authorized to expend not more than twenty thousand dollars of this amount in its manufacture.

In conformity with this law, a board convened by the Secretary of War assembled at the National Armory, Springfield, Mass., on the 3d day of April, 1878, to consider and recommend a magazine-gun, should one be found suitable for the military service. The board consisted of Lieut. Col. J. G. Benton, Ordnance Department; Maj. F. H. Parker,

Ordnance Department; Maj. J. P. Farley, Ordnance Department; First Lieut. (now Capt.) J. E. Greer, Ordnance Department, Recorder.

All persons interested in magazine-guns were invited to submit samples and appear in person, under such rules as might be adopted by the board; the arms submitted to be caliber 0".45, and use the United States service cartridge. The widest circulation was given to this order through the newspapers for over three months, that all persons interested in such an arm might have the time and opportunity to prepare for the trial. The period during which arms could be submitted was afterward extended to the 31st August, so that parties interested had eight months in which to prepare and submit their inventions.

The report of the board is herewith submitted. It recommended the *Hotchkiss magazine-gun*, and upon my recommendation the Secretary of War has approved the action of the board, and of the expenditure under the law of $20,000 in its manufacture. When we take into consideration the many months of patient labor devoted to this subject by so competent a board, and that its investigations were presided over by Lieutenant Colonel Benton, whose great expert knowledge and high scientific attainments are known and acknowledged throughout the profession, there can be no doubt that the conclusion arrived at will receive general approval.

INFANTRY EQUIPMENTS.

In October, 1877, I had the honor of addresssing a communication to the Secretary of War in the matter of the infantry and cavalry equipments that had been recommended by boards of infantry and cavalry officers, and suggesting that such modifications or changes as might have been found by recent field experience to be absolutely necessary be ascertained and approved. With this object in view, it was recommended that the subject be brought to the attention of the General of the Army and the commanding generals of the Departments of the Platte, Dakota, and Columbia, for such suggestions and recommendations as experience in the field would justify.

Reports from all the headquarters were obtained, and the results of the combined recommendations were embodied in a system of infantry equipments that met the approval of the General of the Army. One thousand sets have been made, on his suggestion, and issued for trial. If they meet with approval in the hands of the troops, they will make a saving on each set of $4.23 on the cost of those now used.

ARMAMENT OF FORTIFICATIONS.

For this purpose an estimate of $950,000 has been submitted for the next fiscal year, and the hope is indulged in that Congress will be liberal in its appropriation.

There are but two manufacturing establishments in this country having the facilities and experience necessary for the conversion of guns on the

plan adopted. These are the West Point Foundery, Cold Spring, N. Y., and the South Boston Foundery, Mass., both of which have done foundery work for the government since the commencement of the century. As in all probability we will have to depend on these establishments in the future, the department ought to be in condition to keep them in sufficient orders to preserve the plant and mechanical skill without loss to the companies. Irrespective, however, of any consideration of persons or profit, the present urgent wants of our forts for armament, and the impossibility of supplying it except by a slow and careful process incompatible with the rush of events in impending war, the economy of working at present prices, besides giving the idle mechanic the privilege of laboring for his bread, all appeal to Congress for a large permanent annual appropriation for this national necessity.

The 12¼-inch rifle was completed and mounted at Sandy Hook during the past year. It has been fired only twenty-four rounds with charges varying from 60 to 120 pounds powder, and shot weighing 600 to 700 pounds. The report herewith shows that with 115 pounds powder and 700-pound shot, it gave a velocity of 1,485 feet, with pressure of 33,500 pounds to the square inch; a very satisfactory result, and comparing favorably with results obtained in other countries with guns of the same caliber. To the length of bore and the excellent character of our powder and projectile may be attributed its superiority, if any, over others. While unable to make an exact comparison between this gun and those used abroad as to capacity for work, because of differences in charges of powder and weights of projectiles, the following favorable indications may be noted: The English 25-ton gun, with 85 pounds powder and 600-pound shot, has given 450 foot-tons *less* energy than ours; Krupp's, with 88 pounds powder and 664-pound shot, has given 1,254 foot-tons *less* than ours; the Italian, with 110 pounds powder and 770-pound shot, has only given about 400 foot-tons *more* than ours. Our gun uses only 80 pounds powder and 600-pound shot. With 110 pounds powder and 700-pound projectile our American rifle yields 9,551 foot-tons, an energy about as great as given by any gun known using this charge, and decidedly superior to the Krupp and Italian using heavier charges.

The few rounds fired have developed no weakness in any of its parts, and its further trial should be prosecuted without delay, as it is of the greatest importance to fully test in this higher nature the principles of construction which have realized for us so signal a success in guns of smaller caliber. The trial of a gun of this size is an expensive business, as each fire costs about one hundred dollars; but our coast defenses demand these monster rifles, and the necessary trial guns cannot be tested for endurances for less money.

A 10-inch rifle converted from a 13-inch smooth-bore Rodman has been fired thirty-three rounds satisfactorily, and now awaits further trial, when means are available.

The plan of conversion heretofore followed is known as the muzzle-

insertion, the coiled wrought-iron tube lining being inserted from the muzzle. Defective welds in the coils are the only elements of weakness, but these defects are grave, as it is *impossible* always to detect them in the manufacture of the tubes. The dragging effect of the shot, as it passes through the bore under the great propelling force of the powder, is liable to pull the tube apart at a defective weld, and disable the gun. This can be guarded against by inserting the *lining from the breech* and shouldering the tube in front of the trunnions, thus preventing accidents at those points along the bore subjected to the severest strains. An 8-inch rifle so converted—breech insertion—has been fired over seven hundred rounds with battering charges, and remains in a sound and serviceable condition, showing its entire success. The erosions and developments of welds being less than in guns with muzzle insertions, are also favorable indications; and this plan will be used in future conversions.

The fact that we can utilize our 10-inch smooth-bore guns and produce effective and reliable 8-inch rifles being now fully established, the efforts of the department are naturally and necessarily directed to the further application of conversion in order to provide more powerful rifles by utilizing our 15-inch smooth-bores, now our only dependence for coast positions requiring the heaviest armament. Plans for the production of an 11-*inch rifle* by the conversion of a 15-inch smooth-bore have already been submitted and received your approval. A successful test of such a gun will show that we can procure at a very moderate cost a rifle of largely increased power, having at 2,000 yards an energy at least fifty per cent. greater than the smooth-bore from which it springs, and which it is designed to improve. At 1,500 yards the shot would penetrate 11.2 inches of iron, while the smooth-bore shot would only penetrate 7.5 inches.

Breech-loading 8-inch rifle.—In my report of 1876, I remarked that—

Whatever differences of opinion may exist as to the relative merits and efficiency of *muzzle* and *breech* loading cannon of large caliber (the former being exclusively used in England, the latter almost universally adopted on the continent of Europe), there can be no question that in casemated works the latter system possesses obvious and paramount advantages, such advantages as are generally admitted in determining on the proper armament for ships of war. The subject has, therefore, not escaped the attention of this department, and the Board on Experimental Guns, of date the 10th June, 1875, "recognizing breech-loading rifles for casemate service to be a great desideratum, believed that a portion of the appropriation should be expended in this direction," and recommended "that a sufficient sum be used for the conversion of two 10-inch smooth-bore Rodman cast-iron guns into 8-inch breech-loading rifles," submitting at the same time specific plans of alteration, &c. The want of funds available for the purpose prevented any action thereon, but experiments to determine the feasibility of converting some of our smooth-bore Rodmans into breech-loading rifles should be undertaken at an early day.

Since that time an 8-inch breech-loading rifle has been made by lining a 10-inch smooth-bore with a steel-jacketed coiled-wrought-iron tube inserted from the breech, the jacket being prolonged to the rear, thus

adapting it to receive its round wedge *fermeture*. It has been fired thirty-four rounds with battering charges, and now awaits further trial. Its thorough trial is a matter of grave importance, as its success will show our ability to engraft the thoroughly tested and approved system of *fermeture*, made famous by Krupp, upon our converted cast-iron guns, and afford strong evidence that we can use it in any desired original breech-loading construction of cast iron, and for the heaviest caliber.

Experimental guns.—On the 15th April, 1878, I had the honor to recommend an appropriation of $117,600 for the trial of experimental guns procured by this department under the law of June 6, 1872. My recommendation, with the report and detailed estimate of the Ordnance Board, received your approval, and was submitted to Congress favorably indorsed. No action was taken upon it.

These guns were prepared several years ago, upon the recommendation of a board, and under a specific provision of law. On the 20th January, 1875, the President sent a special message to Congress on the subject of armament of fortifications, inclosing a special report from the Chief of Ordnance, and recommending $250,000 "for proving-ground and experiments and tests of heavy ordnance." In that report I stated that the guns "designated by a board of officers appointed by the Secretary of War * * will probably be ready for trial in the early spring." "Funds necessary for this purpose should be appropriated." When the sundry civil bill was under discussion in the House, the President's message and my report were quoted from in favor of an appropriation for testing these guns, but the House refused to make an appropriation. In my annual report of 1876, I again called special attention to this subject. During the last session another effort was made, as above stated, and amendments covering the estimate were submitted in both Senate and House, but no appropriation was made. This matter is again brought to the attention of Congress, in the hope that the necessary funds will be given for these very important trials.

Fuses.—The war having left us with all sorts of fuses, but with no single one exhibiting any marked superiority over all others, it was deemed of the first importance to carry out a course of experiments, and make a thorough investigation of the subject. The Ordnance Board has, from time to time, made trials of the varieties on hand, and of new devices presented by inventors. Its detailed report is submitted. While no decided superiority in favor of any one has been established, much has been done in clearing the field of examination of those without merit, and confining future studies and trials to narrower limits.

The machine gun as an auxiliary arm is an established fact in all armies, and the interest that has attended the success of the Gatling gun during the past decade has stimulated invention in that direction, so that many new devices have been pressed upon the attention of this department for trial and recognition. The last two tried by the Ordnance Board at Sandy Hook were the Lowell Battery Gun, caliber .45″, and

the Taylor Battery Gun, caliber .43″, and the reports are herewith submitted.

Of the Lowell, the board was so well impressed with the merits of the gun as to recommend that a number, with all the latest improvements, be procured for trial in the field in comparison with the Gatlings now in service.

Of the Taylor, while commending the ingenuity of its construction, the board did not approve of its feeding arrangement, which will require material modification and improvement before any further action can be taken.

I cannot close this summing up without commending the most valuable labors and services of the members of the Ordnance Board—Colonels Crispin, Treadwell, and Baylor, and Captain Phipps, recorder—in the many important matters committed to them for investigation and determination. In an especial manner do I wish to give full measure of credit to Lieut. Col. S. Crispin, for his distinguished services as Constructor of Ordnance. To his large practical experience, great technical knowledge, clear and comprehensive intellect, do I attribute, in a marked degree, the decided success that has crowned our endeavors in improving the armament of our coast.

POWDER MILL AND DEPOT.

I again renew my recommendation for an appropriation of $100,000 for the establishment of a powder mill for the manufacture of gunpowder, and a depot for its storage and preservation. Our principal storage room is found in damp and unsuitable magazines and casemates of our forts, where the gunpowder deteriorates very rapidly. Well-constructed magazines in a proper locality would in a few years save the cost of their erection by preventing this deterioration and loss.

ORDNANCE NOTES.

I have the honor to invite attention to several interesting papers herewith, on instruments and material used by the department, on experiments, investigations, and discussions in connection with gunnery, and other matters, which give an insight into the labors of the department and the variety of subjects that come within the field of study of an ordnance officer.

These papers have been selected as of importance to the service, and I desire to give proper credit to Majors Lyford and Farley, Captain McKee, Lieutenants Metcalfe, Smith, Lyle, and Russell, for such valuable contributions.

LIEUTENANT LYLE'S REPORT ON LIFE-SAVING APPARATUS, ETC.

Early in 1875 the Secretary of the Treasury applied for assistance in prosecuting experiments for improving the life-saving apparatus used in this country, then under the charge of Capt. J. H. Merryman, U. S.

Revenue Marine. On my recommendation, the Secretary of War directed that the Board on Experimental Guns, then in session in New York, be charged with this duty, the experiments to be conducted at Sandy Hook, N. Y. Their many important and special duties not admitting of as close an application to this matter as its importance and the exigencies of its service demanded, it was decided to place the entire subject in charge of one officer as a special service. In June, 1877, Lieut. D. A. Lyle, Ordnance Department, was "specially assigned to this duty," and his very interesting and valuable report is herewith submitted.

The objects of these experiments are as follows: To extend the range of the shot-line; to determine, if possible, the proper form, caliber, and kind of gun or mortar best suited for life-saving purposes; to reduce the weight of such apparatus to the minimum amount consistent with efficiency; to secure a shot-line of such size, material, and strength as will be most valuable; to determine the kind and quantity of powder to be used, and the charges that can be employed with safety for the several lines; to secure the best form and size of faking-box; and to find the best relative positions for the faking-box and the gun.—*Superintendent Kimball's Report of* 1877 *on Life-saving Service.*

While Lieutenant Lyle lays little claim to any great originality in the improvements and changes suggested, his ability, industry, and research have accomplished much of present great value, and which will materially aid in future experiments and development. The extraordinary range attained by him with his improved shot and line of 694⅔ yards is greater than any range heretofore obtained either in this country or abroad. It gives me great gratification to be able to record so much success in so short a period, by an officer whose attention was first drawn to this new field of research but twelve months ago. This department is now supervising the construction of guns, carriages, faking-boxes, &c., and I have reason to believe that the assistance already rendered to the Life-saving Service is deemed of sufficient value to justify its continuance.

MILITIA.

Article 1, section VIII, of the Constitution empowers Congress "to provide for organizing, arming, and disciplining the militia," &c.

The Revised Statutes, section 1661, provide that—

The annual sum of two hundred thousand dollars is appropriated, to be paid out of any money in the Treasury not otherwise appropriated, for the purpose of providing arms and equipments for the whole body of the militia, either by purchase or manufacture, by or on account of the United States.—*Act of 23d April*, 1808.

The latest published returns of the militia force give—

Organized	93, 697
Unorganized	3, 734, 693

The present annual appropriation of $200,000 is insufficient to provide the arms and equipments necessary to encourage the formation of new organizations, and to keep the organized force in proper condition. This amount ought to be largely increased. New organizations ought to be

encouraged and fostered by every means possible. The whole body of the militia ought to be organized and disciplined as the Constitution provides it should be, and ample provision should be made for arming and equipping new organizations as rapidly as they are formed. Until the militia is thus placed on a proper footing, in condition to be efficiently handled when called out, a standing army of some magnitude cannot be dispensed with. This matter deserves and should receive the serious attention of Congress.

The act approved March 3, 1875, provides that, under certain conditions, credits be given to the several States and Territories for the sums charged to them respectively for arms, &c., which were issued to them between January 1, 1861, and April 9, 1865, and charged against their quotas under the law for arming and equipping the militia. It is made the duty of the Secretary of War to refuse a credit "if he shall find that any of said arms or ordnance stores have been sold," &c. At the close of the war some of the States sold portions of the arms, &c., in their possession, realizing but a portion of the values charged against them on the books of this office. The arms ought not, in my opinion, to have been charged to the States on their quotas, but should have been accounted for as issues to the Army, and the loss of values should have fallen on the United States. It seems to me that these charges against individual States ought to be removed, and that the spirit of the law of 1875 be extended, so as to permit credits to be given States for the difference between the prices charged and the prices realized from sale. I respectfully recommend a modification of the act of March 3, 1875, in this regard.

During the last fiscal year the following arms were issued under the law of July 3, 1876, providing for certain issues to the Territories and States bordering thereon: Oregon, 300 arms, 10,040 cartridges; Idaho, 2,000 rifles, 100,000 cartridges; and under the same act (since 1st July), and during the recent Indian disturbances in that section of country, to Oregon 613 arms, 72,928 cartridges.

The act of May 16, 1878, and joint resolution of June 7, 1878, increased the number of arms permitted to be issued to the Territories by the act of 1876 from 500 to 2,000, with necessary ammunition. The provision of these laws enabled this department, during the recent Indian troubles, to issue to Washington Territory 1,372 rifles, 87,462 cartridges.

Colleges.—Section 1225 Revised Statutes, as amended by act of July 5, 1876, authorizes the issue of arms, artillery, &c., to colleges where an officer of the Army has been detailed, the number not to exceed thirty, &c. The law calls for material modifications. There should be more permanency in the detail, and in the institution that is to receive these benefits. A college that is to be provided with an officer and arms should be specially designated by the legislature of the State interested, and service at a college ought not to be optional, but be considered a military duty to which all officers are liable. Governmental supervision

and inspection of these colleges to the extent of the military training, discipline, and study, should be a condition attached to the acceptance of the liberality of the general government. The providing of officers and arms makes these colleges, in a sense, a portion, and a very important portion, of the military establishment, because of the direct influence they will exercise over the efficiency of the militia; supplying, as they will, from year to year, a number of competent instructors in all that is necessary to make men good soldiers, and keeping alive the military spirit of the nation through the enthusiasm of the young. I recommend that Congress be asked for further legislation on this subject.

LAIDLEY'S CAVALRY FORGE.

Upon the intimation of the Cavalry Board that a cavalry forge for that service was a necessity, one was devised by Col. T. T. S. Laidley, Ordnance Department, and manufactured at the Watertown Arsenal under his personal supervision. Being sent into the field for trial—a smithshop on wheels—its merits and capacity were proved so conclusively, during a summer's hard campaign with a large command having many animals and wagons, that Colonel Merritt, Fifth Cavalry, asked that one be issued to each company of the regiment. Last January twelve were ordered to be made, and in May, by direction of the General of the Army, they were distributed among the regiments of cavalry. Since then others have been called for, and are now being manufactured for issue.

HOTCHKISS MOUNTAIN BREECH-LOADING RIFLE.

Early in 1876, Colonel Miles, Fifth Infantry, suggested that a light field-gun weighing less than 500 pounds be provided for service on the plains, to replace the obsolete mountain howitzer. The subject was submitted to the Ordnance Board for consideration, with the remark "that a rifled gun, probably a breech-loader, that can travel with cavalry, and has an effective shell range beyond that of rifled small-arms, not less than 1,500 yards, would probably meet the requirements of the service." While under consideration, Mr. B. B. Hotchkiss presented for examination and trial a light breech-loading rifle that gave promise of efficient service on the frontier, and fulfill the conditions of mobility, range, and accuracy. One was procured and issued to the Department of Dakota in 1877, and used in the field that summer. It weighs 116 pounds, and its caliber is 1.65 inches. It uses a charge of 6 ounces powder, and a percussion shell weighing 2 pounds. While many defects in its mechanism, and in the carriage and ammunition, have been pointed out after the experience of a campaign, showing that modifications are desirable to add to its effectiveness, it did excellent work. I am informed that Colonel Miles expressed himself as satisfied that it had rendered efficient service, and was a valuable weapon. With all its defects, others have been called for, and the five now in possession of the department will be issued to the troops.

CLERICAL FORCE.

Attention is respectfully invited to my estimate, again made, asking for six clerks in addition to the present clerical force of this bureau.

This estimate conforms to the number and grades for which appropriation was made for the fiscal year ending June 30, 1876, which force was barely sufficient to transact the business of this office promptly and efficiently.

The present clerical force is insufficient to transact the business which by law is devolved on this office. At this time over four thousand property-returns remain unsettled. This delay in the examination and adjustment of the property accountability of officers of the Army is often the cause of injustice to officers and of pecuniary loss to the United States. Other important office work is also delayed.

To give some idea of the clerical work done in this office during the past twelve months, the following statement is submitted:

Number of cash accounts of disbursing officers examined and forwarded to the accounting officers of the Treasury for settlement	219
Number of property returns examined	2,567
Number of property returns audited and closed	1,770
Number of requisitions received from the Army and acted upon	1,428
Number of reports received from the armory, arsenals, and the Army, on manufacture, trials, and tests of war materials, &c., and acted upon	2,725
Number of letters received	19,641
Number of letters written and sent	18,995
Number of orders sent to the various arsenals for the issue of supplies	1,849
Number of blanks, public documents, and other printed matter for the use and information of the military establishment, &c., prepared and distributed	35,554

This office is divided into three divisions, each requiring a clerk of great experience and knowledge in charge, and the chiefs of these divisions have been and should now be graded and paid as fourth-class clerks.

I have the honor to submit the following papers, heretofore referred to:

Appendix A.—Statement of principal articles procured by purchase and fabrication at the arsenals during the year ended June 30, 1878.

Appendix B.—Statement of ordnance, ordnance stores, &c., issued to the military establishment, exclusive of the militia, during the year ended June 30, 1878.

Appendix C.—Apportionment, for the fiscal year ended June 30, 1878, of the annual appropriation of $200,000 for arming and equipping the militia, under sections 1661 and 1667 Revised Statutes.

Appendix D.—Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1877, to June 30, 1878, under section 1667 Revised Statutes.

Appendix E.—Statement of ordnance, ordnance stores, &c., distributed to colleges from July 1, 1877, to June 30, 1878, under section 1225 Revised Statutes.

Appendix F.—Statement of ordnance stores, &c., distributed to the

Territories and States bordering thereon, from July 1, 1877, to June 30, 1878, under the joint resolutions of July 3, 1876; March 3, 1877; March 9 and June 7, 1878.

Appendix G.—Showing stations and duties of the officers of the Ordnance Department on the 30th of June, 1878.

Appendix H.—Electrical interrupter.

Appendix I.—The application of formulas and general tables to problems in practical gunnery.

Appendix K.—Manufacture and classification of leather.

Appendix L.—European rifled siege howitzers and mortars.

Appendix M.—Penetrating power of projectiles.

Appendix N.—Recoil dynamometers.

Appendix N^1.—Tests of lubricants for machinery.

Appendix N^2.—Tests of cartridge metals.

Appendix O.—Anomalies of small-arm practice.

Appendix P.—Life-saving apparatus.

Appendix Q.—Report of the Ordnance Board on the experimental guns procured under act of July 6, 1872, with estimate for their exhaustive trial, as contemplated by law.

Reports of the Constructor of Ordnance, viz:

Appendix R.—Construction of 12.25-inch muzzle-loading rifles.

Appendix R^1.—10-inch muzzle-loading rifle, converted.

Appendix R^2.—Converted 8-inch muzzle-loading rifle, breech insertion of tube.

Appendix R^3.—Converted 8-inch breech-loading rifle, round wedge *fermeture.*

Appendix R^4.—Carriage for 8-inch breech-loading rifle (altered from a barbette carriage for 10-inch smooth-bore gun).

Reports of the Ordnance Board, viz:

Appendix S.—Trial of the Lowell battery gun, caliber .45″.

Appendix S^1—Trial of the Taylor battery gun, caliber .43″.

Appendix S^2.—Trial of various fuses, with description thereof.

Appendix S^3.—Trial of 8-inch muzzle-loading rifle, breech insertion of tube.

Appendix S^4.—Trial of the 12.25-inch rifle.

Appendix S^5.—Trial of the 10-inch muzzle-loading rifle, No. 1.

Appendix S^6.—Trial of the 8-inch breech-loading rifle.

Appendix T.—Report of the Board of Officers convened in conformity with the act of November 21, 1877, to select a magazine-gun for the military service.

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

APPENDIX A.

Statement of principal articles procured, by fabrication at the arsenals and by purchase, during the year ending June 30, 1878.

CLASS I.

17 Gatling guns, caliber .45, 5 barrels, short.
11 Gatling guns, caliber .45, 10 barrels, long.
1 Lowell battery gun, caliber .45.
1 12.25-inch rifled gun.
39 coiled wrought-iron tubes for 8-inch converted rifles.

CLASS II.

36 carriages and limbers for Gatling guns, caliber .45.
53 tripods for Gatling guns, caliber .45.
12 cavalry forges, Laidley's.

CLASS III.

10 buckets, various.
2,145 feed-cases for caliber .45 Gatling guns.
1,000 feed-tubes for Lowell battery gun.
42 gun-covers, various.
30 handspikes, trail.
286 paulins, 12 by 15 feet.
4 paulins, 20 by 30 feet.
1 pendulum hausse, 3-inch.
6 punches for pendulum hausses.
2 quoins.
2 rammers and staves for 8-inch rifle.
100 securing stakes.
42 sponges and rammers, various.
5 sponges and staves, various.
22 sights for cannon, various.
6 cannon-spikes.
7 tangent scales.
102 tompions, various.
41 vent-pieces.
12 fuse-plug wrenches.
24 parts of artillery implements.

CLASSES IV AND V.

50 6-pounder shot, fixed.
25 6-pounder case.
46 12-pounder shells, fixed.
25 12-pounder case.
348 24-pounder howitzer shells, fixed.
500 1.65-inch Hotchkiss shells.

25 3-inch Butler shells.
200 3-inch Hotchkiss shells.
1,100 3-inch Hotchkiss case.
1,150 3-inch Hotchkiss canister.
1,005 3-inch Sawyer canister.
50 3.15-inch shells.
25 3.5-inch Butler shot.
25 3.5-inch Butler shells.
50 3.67-inch Hotchkiss canister.
10 4.5-inch Hotchkiss canister.
11 4.5-inch Sawyer canister.
202 8-inch Butler shot.
5 8-inch Dennet shot.
23 8-inch experimental shot.
15 8-inch experimental canister.
20 8-inch Sawyer canister.
50 10-inch Butler shot.
30 12.25-inch Butler shot.

CLASS VI.

2,000 Springfield carbines, caliber .45.
9,954 Springfield rifles, caliber .45.
1,050 Springfield "cadet" rifles, caliber .45.
1 Springfield officer's rifle, caliber .45.
2 Schofield's Smith and Wesson revolvers, caliber .45.

CLASS VII.

2,702 sets infantry equipments.
100 graduated felt saddle-cloths.
10,005 saddle-blankets.
3,000 curry-combs.
2,922 sets knives, forks, and spoons.
7,875 meat-ration cans.
18,552 appendages for small-arms.

CLASS VIII.

26,358 cartridge-bags, filled, various.
3,949,451 rifle ball-cartridges, caliber .45.
766,200 carbine ball-cartridges, caliber .45.
786,202 revolver ball-cartridges, caliber .45.
106,800 revolver blank-cartridges, caliber .45.
1,000 rifle ball-cartridges, caliber .50, experimental.
33,700 lead balls, caliber .45.
10,000 pounds English pebble powder.
90,300 pounds hexagonal powder.
1,952 pounds rifle powder.
2,110 electric cannon-primers.
121,750 friction-primers.
162 fuses, experimental, various.
600 signal-shells.
5,000 cartridge-primers, experimental.
200 fuse-plugs, brass.

CLASS IX.

108 blocks, various.
82 chocks, various.
1 cradle for 10-inch gun.
1 gun-rest.
1 hand-cart.
2 intrenching tools.
8 platforms for mortars.
7 platforms for siege-carriages.
39 rollers, various.
43 shifting-planks.
1 set staging-planks for gun-lift.
16 skids.
2 sheaves for siege-gin.
28 trunnion-rings.
1 truck, Ball's improved.
5 hydraulic jacks.
38 loading-cranes.
2 poles for sling-carts.
1 wheel for sling-cart.

CLASS X.

938 sabots, various.
300 tin straps, various.
340 plugs for trowel-bayonets.
33,624 spare parts for small-arms.
97,750 parts of infantry equipments.
2,880 parts of cavalry accouterments.
52,285 parts of horse equipments.
52,985 cartridge-bags, empty, various.
26,900 cartridge-shells, caliber .45, experimental.

MISCELLANEOUS.

644 arm-chests.
3,775 boxes, packing, wood.
648 boxes, packing, tin.
1,901 bolts and nuts, various.
96,444 pounds barrel-molds.
1,488 tin cans.
3 cartridge-gauging machines.
1 cartridge-heading machine.
1 cartridge-stamping machine.
3 cartridge-weighing machines.
1 bullet-making machine.
2 bullet-lubricating machines.
1 drilling machine.
1 grooving machine.
1 cutter grinding machine.
1 chain-link machine.
1 milling machine.
1 metal-testing machine.
1 oil-testing machine.
1 machine for making canteen-rings.
1 mortising machine.
1 hydraulic punching machine.
1 cold-pressing and stamping machine.

1 screw-slotting machine.
1 slotting machine.
1 shaping machine.
1 recoil dynamometer.
2 lathes.
3 sets standard gauges for cartridges.
13 sample-boards, various.
1 star-gauge, ring, and points.
1 ring-gauge.
162 boxes leather blacking.
3,000 pounds harness-oil.
5 gallons lacquer.
215 cast-iron heating-stoves, for quartermaster's department.
1 tool-chest, armorer's.
32 pounds black wax.
24,892 pounds white lead.
10,701 pounds paint.
2,709 sides leather.
25,593 pounds leather.
27,650 pounds rope, twine, and thread.
292,557 pounds iron beams.
78,448 pounds sheet-copper.
2,810 tons coal.
6,480 tools and utensils.

APPENDIX B.

***Statement of ordnance, ordnance stores, &c. issued to the military establishment (except the militia) during the fiscal year ended June* 30, 1878.**

CLASS I.

3 Gatling guns, caliber .45, long barrel.
10 Gatling guns, caliber .45, short barrel.
2 Gatling guns, caliber .50.
2 Gatling guns, caliber 1 inch.
15 3-inch rifled guns.
1 6-pounder bronze gun.
7 12-pounder bronze guns.
2 12-pounder mountain howitzer.
4 24-pounder Cœhorn gun.

CLASS II.

10 carriages for short barrel Gatling gun.
7 carriages and limbers for long barrel Gatling gun.
2 caissons and limbers for Gatling gun.
2 3-inch carriages, without limbers.
12 3-inch carriages and limbers.
6 3-inch caissons and limbers.
2 4½-inch carriages and limbers.
1 6-pounder carriage and limber.
8 12-pounder carriages and limbers.
1 12-pounder prairie carriage and limber.
4 12-pounder mountain howitzer carriages.
2 8-inch siege howitzer carriages.
6 limbers for 12-pounder carriage.
4 24-pounder mortar beds.
1 mortar-wagon.
11 cavalry forges, Laidley's.
2 portable forges.
1 traveling forge.

CLASS III.

3 baskets for mortar implements.
24 sponge buckets.
35 tar buckets.
98 watering buckets.
1 breech-sight for 6-pounder gun.
1 breech-sight for 12-pounder mountain howitzer.
7 front-sights for 3-inch gun.
6 front-sights for 12-pounder gun.
3 front-sight covers.
1 front-sight tap for 12-pounder mountain howitzer.
14 forge-buckets.
7 fuse-blocks.

15 fuse-cutters.
2 fuse-extractors.
6 fuse-gauges.
10 fuse-gouges.
12 fuse-mallets.
6 fuse-plug reamers.
9 fuse-plug wrenches.
8 fuse-saws.
4 fuse-setters.
21 fuse-wrenches.
1 gunner's calipers.
38 gunner's gimlets.
9 gunner's haversacks.
3 gunner's levels.
16 gunner's pincers.
4 gunner's quadrants.
6 gunner's sleeves.
117 handspikes.
20 sets artillery harness, 2 horses, lead.
12 sets artillery harness, 2 horses, wheel.
10 sets harness for two horses, short barrel Gatling gun.
6 sets harness for mountain howitzer.
72 harness sacks.
74 lanyards.
11 pack saddles and bridles, complete.
26 paulins, 5 by 5 feet.
5 paulins, 6 by 10 feet.
74 paulins, 12 by 15 feet.
2 pendulum hausses, 6-pounder gun.
12 pendulum hausses, 12-pounder gun.
19 pendulum hausses, 3-inch gun.
29 pendulum hausse pouches.
18 pendulum hausse seats.
4 pinch bars.
77 priming wires.
24 prolonges.
1 quoin.
8 rammers and staves, 8-inch gun.
46 sponge covers, 3-inch gun.
5 sponge covers, 6-pounder gun.
34 sponge covers, 12-pounder gun.
15 sponge covers, 12-pounder mountain howitzer.
21 sponge covers, 10-inch gun.
8 sponge covers, 24-pounder Coehorn mortar.
68 sponges and rammers, 3-inch gun.
7 sponges and rammers, 6-pounder gun.
33 sponges and rammers, 12-pounder gun.
10 sponges and rammers, 12-pounder mountain howitzer.
8 sponges and rammers, 24-pounder Coehorn mortar.
4 sponges and staves, 3-inch gun.
8 sponges and staves, 8-inch gun.
5 sponges and staves, 10-inch gun.
3 sponges and staves, 15-inch gun.
8 tangent scales.
1 telescope sight for heavy gun.
67 thumbstalls.

29 tompions, 3-inch gun.
23 tompions, 12-pounder gun.
4 tompions, 12-pounder mountain howitzer.
1 tompion, 100-pounder Parrott gun.
10 tompions, 8-inch gun.
17 tompions, 10-inch gun.
12 tompions, 15-inch gun.
4 tompions, 24-pounder Coehorn mortar.
28 tow hooks.
34 tube pouches.
38 vent covers.
46 vent pieces, field gun.
31 vent punches.
6 vent plug taps.
4 wipers for mortars.
27 worms and staves.
13 adjusting screw wrenches.
13 clamps for worm gear.
3 drifts.
954 feed cases.
30 Gatling gun covers.
2 gear extractors.
2 holders for wiping rods.
16 pin wrenches.
14 rear guide nut wrenches.
39 screw drivers.
2 screw drivers and fork wrenches.
13 shell drivers.
2 shell extracting rods.
20 wiping rods.

Classes IV and V.

50 6-pounder shot.
25 6-pounder case.
25 6-pounder canister.
125 12-pounder shot.
525 12-pounder shell.
1,204 12-pounder case.
1,002 12-pounder canister.
280 24-pounder shell.
200 8-inch shot.
50 8-inch shell.
50 8-inch canister.
100 15-inch shot.
100 15-inch shell.
236 3-inch shot.
1,140 3-inch shell.
623 3-inch case.
520 3-inch canister.
100 30-pounder shot.
100 30-pounder shell.
200 4½-inch shell.
100 100-pounder shot.
100 100-pounder shell.

CLASS VI.

Muzzle-loading.

835 Springfield rifle-muskets, caliber .58.
2 smooth-bore muskets.
10 rifle-muskets, caliber .54.

Breech-loading.

143 Sharps' carbines, caliber .50.
100 Sharps' carbines, caliber .52.
41 Springfield carbines, caliber .50.
764 Springfield carbines, caliber .45.
512 Springfield rifles, caliber .50.
1,172 Springfield rifles, caliber .45.
5 double-barreled shot-guns, cleaned and repaired.
24 Remington revolvers, caliber .44.
410 Colt's revolvers, caliber .44.
658 Colt's revolvers, caliber .45.
182 Schofield's Smith and Wesson revolvers, caliber .45.
14 artillery sabers.
271 cavalry sabers.
68 musician's swords.
56 non-commissioned officer's swords.
27 riflemen's knives.
605 trowel bayonets.

CLASS VII.

55 artillery saber-belts.
55 artillery saber belt-plates.
142 carbine cartridge-boxes.
963 carbine cartridge pouches.
2,154 carbine slings.
2,225 carbine-sling swivels.
1,343 pistol-cartridge pouches.
3,482 pistol holsters.
558 saber attachments.
1,687 saber belts.
1,687 saber-belt plates.
106 saber knots.
5 sets of infantry equipments.
39 leather bayonet scabbards.
1,490 steel bayonet scabbards.
634 trowel bayonet scabbards.
98 brace yokes.
10,315 canteens and straps.
143 cap pouches.
5,049 cartridge-boxes, caliber .45.
177 cartridge-boxes, caliber .50.
39 cartridge-boxes, caliber .58.
354 cartridge boxes, No. 1.
409 cartridge boxes, No. 2.
39 cartridge box belts.
39 cartridge box belt-plates.
39 cartridge box plates.

249 cartridge loops.
1,007 carrying braces.
4,358 clothing bags.
2,768 coat straps.
8,490 forks.
211 frogs.
3,560 gun slings.
6,821 haversacks.
20 knapsacks.
8,496 knives.
10,201 meat cans.
3 musician's steel sword-scabbards.
731 scabbards for intrenching tools.
399 shoulder braces.
8,489 spoons.
5 sword belts and plates, non-commissioned officer's.
7,288 tin cups.
313 valises.
616 valise straps.
56 waist-belts and plates, non-commissioned officer's.
2,564 waist-belts, private's.
2,559 waist-belt plates, private's.
43 ball screws.
1,172 brush wipers and thongs.
316 headless-shell extractors.
3,364 screw drivers.
121 spring vises.
332 tumbler punches.
188 wiping rods.
82 wipers.
2,378 bridles, curb.
1,352 bridles, watering.
351 carbine-sockets.
630 cruppers.
6,141 curry-combs.
200 forage-sacks.
3,489 girths.
7,138 halters and straps.
11,223 horse-brushes.
144 horse-covers.
10,735 lariats.
2,297 links.
7,453 nose-bags.
4,600 picket-pins.
1,199 saddles, leather covered.
3,236 saddle-bags.
1,458 saddle-blankets, artillery.
5,973 saddle-blankets, cavalry.
563 saddle-cloths, felt.
6,158 side-lines.
6,495 spurs.
7,841 spur-straps.
4,362 surcingles.
2,270 stirrups.
3 stirrups with guidon sockets.
2,315 stirrup straps.
79 sweat leathers.

CLASS VIII.

SMALL-ARM AMMUNITION.

Paper cartridges.

901,600 rifle ball-cartridges, caliber .58.
11,000 rifle-ball cartridges, caliber .54.
126,000 carbine ball-cartridges, caliber .52.
69,500 revolver ball-cartridges, caliber .44.
3,000 revolver blank cartridges, caliber .44.

Metallic cartridges.

5,000 Gatling ball-cartridges, caliber 1 inch.
2,000 Gatling canister-cartridges, caliber 1 inch.
191,400 rifle ball-cartridges, caliber .50.
13,000 carbine ball-cartridges, caliber .50.
1,487,640 rifle ball-cartridges, caliber .45.
735,200 carbine ball-cartridges, caliber .45.
314,785 rifle blank cartridges, caliber .45.
276,374 revolver ball-cartridges, caliber .45.
120,804 revolver blank cartridges, caliber .45.
13,640 percussion-caps.
1,000 pounds buckshot.

Ammunition for field-guns.

100 blank cartridges, 24-pounder howitzer.
6,210 blank cartridges, 12-pounder mountain-howitzer.
12,522 blank cartridges, 12-pounder gun.
2,520 blank cartridges, 6-pounder gun.
11,759 blank cartridges, 3-inch gun.
908 blank cartridges, 1-pound charge.
2,675 blank cartridges, ½-pound charge.
110,059 friction-primers.
2,602 fuses.
29,100 pounds cannon powder.
7,000 pounds mammoth powder.
15,270 pounds mortar powder.
500 pounds musket and rifle powder.
457 signal-rockets.

CLASS IX.

14 blocks, whole.
25 blocks, half.
25 blocks, quarter.
10 blocks, 4 by 12 inches, 46 inches long.
15 blocks, 2 by 12 inches, 46 inches long.
7 blocks, 12 by 12 inches, 10 feet long.
3 iron blocks, double.
3 iron blocks, treble.
2 iron blocks, quadruple.
1 set staying-blocks.
3 hand-carts.
2 large sling-carts.

22 gun-chocks.
40 roller-chocks.
31 wheel-chocks.
1 gun-cradle.
1 casemate-gin.
2 siege-gins.
431 intrenching tools.
2 hydraulic jacks.
1 lifting jack.
11 platforms for siege-carriage.
2 platforms for mortar.
2 differential pulleys.
12 long rollers.
12 short rollers.
43 shifting planks.
16 skids.
1 sling chain.
1 sling rope.
3 stadia, brass.
2 trunnion loops.
1 trunnion rings.
2 casemate trucks.
1 store truck.

Class X—I.

6 butt-gear pins.
1 clamp screw.
12 extractor hooks.
6 extractor pins.
6 firing pins.
6 firing plugs.
4 locks.
12 lock springs.
12 lock-spring screws.
4 oscillating double worms.
4 spiral springs.

Class X—II.

15 ammunition chests.
5 ammunition-chest keys.
3 axle bodies for 3-inch carriages.
6 axle sleeves for altered 15-inch carriages.
2 caisson stocks.
2 chains, Nos. 1 and 2.
62 cold shut links.
15 escutcheon sockets for 10-inch carriages.
10 escutcheon sockets for 15-inch carriages.
28 fellies.
6 forks for 3-inch gun limber.
16 linchpins, No. 1.
8 linch washers.
4 iron naves for 3-inch carriages.
4 nave bands.
39 poles for field carriages.
4 poles for siege carriages.

12 pole yokes.
2 pole-yoke-prop rings.
1 splinter bar.
56 spokes.
6 straps for ammunition chests.
3 trail stocks.
4 thills for 12 pounder mountain howitzer.
20 tire bolts and nuts.
2 tire bands.
2 tongues for sling carts.
44 washers and nuts.
18 wheels for Gatling gun carriages.
37 wheels for field carriages.

CLASS X—III.

16 artillery bridles.
17 artillery collars.
12 artillery girths.
29 artillery halters and straps.
6 artillery saddles.
72 rosettes for artillery bridles.
4 lashing ropes.
2 lead traces.
43 pole pads.
28 pole straps.
15 rammer-heads for 6-pounder gun.
12 sponge-heads for 6-pounder gun.
12 sponge-heads for 12-pounder mountain howitzer.
4 sponges.
107 sponges for 3-inch gun.
51 sponges for 6-pounder gun.
78 sponges for 12-pounder gun.
35 sponges for 12-pounder mountain howitzer.
8 sponges for 8-inch gun.
24 sponges, spring cover, for 15-inch gun.
6 seats for drivers' saddles.
4 traces for Gatling gun harness.
2 wheel traces.
167 whips.

CLASS X—IV.

200 sabots for 8-inch Butler shot.
260 sabots for 15-inch shot and shell.
50 tin straps.

CLASS X—VI.

Parts of Springfield rifles, caliber .50″.

MODEL 1866.

10 ejector-spring caps.
25 ejector-spring-cap screws.
10 firing-pin nuts.
5 friction springs.
5 friction-spring screws.

40 hinge screws.
80 hinge-screw nuts.
10 hinge-strap screws.
5 rear sight bases.
10 rear sight leaves.
10 stocks.

MODEL 1868.

20 bands, lower.
20 bands, upper.
3 band swivels.
12 band-swivel screws.
12 breech blocks.
23 breech-block-cap screws.
12 cam latches.
7 cam-latch springs.
12 ejector studs.
25 ejector springs.
2 ejector-spring spindles.
24 extractors.
7 firing pins.
7 firing-pin screws.
7 firing-pin springs.
20 locks.
20 lock-plates.
3 main-springs.
15 ramrods.
60 ramrod stops.
62 rear sights.
20 rear sight bases.
20 rear sight leaves.
20 rear sight leaf screws.
20 rear sight joint screws.
20 rear sight base screws.
20 rear sight slides.
20 rear sight springs.
3 sear springs.
40 side screws.
20 side-screw washers.
65 stocks.
50 tang screws.
10 tips for stock.
13 tumbler screws.

Parts of Springfield rifle, caliber .45.

995 bayonets.
152 bayonet clasps.
185 bayonet clasp screws.
102 bayonet clasp stop screws.
240 trowel bayonet plugs.
73 lower bands.
776 upper bands.
147 band springs.
60 band spring swivels.
4 band swivel hooks.

124 band swivel screws.
2 band swivel pins.
2 band swivel hook pins.
6 barrels.
24 breech blocks.
98 breech block caps.
336 breech block cap screws.
20 breech block screws.
30 breech screws.
88 bridles.
317 bridle screws.
28 butt plates.
204 butt plate screws.
65 cam latches.
734 cam latch springs.
22 cover springs.
22 cover friction springs.
22 cover friction spring screws.
22 cover stud pins.
50 ejectors.
1,780 ejector springs.
1,242 ejector spring spindles.
97 ejector studs.
308 extractors.
1,081 firing pins.
939 firing pin springs.
467 firing pin screws.
29 front sights.
25 guard bows.
10 guard bow screws.
375 guard bow swivels.
596 guard bow swivel screws.
284 guard bow nuts.
36 guard plates.
514 guard screws.
162 hammers.
132 hinge pins.
44 hinge pin studs.
1 lock.
27 lock plates.
637 main springs.
194 main spring swivels.
242 main spring swivel rivets.
177 ramrods.
509 ramrod stops, upper.
10 receivers.
100 rear sights.
120 rear sight bases.
419 rear sight base screws.
335 rear sight base springs.
517 rear sight joint pins.
397 rear sight leaves.
738 rear sight slides.
666 rear sight slide springs.
943 rear sight slide spring rivets.
141 sears.

324 sear screws.
512 sear springs.
324 sear spring screws.
567 side screws.
93 side screw washers.
283 stocks.
134 swivel bars.
212 swivel bar rings.
22 swivel bases.
228 tang screws.
32 tips for stocks.
82 tip screws.
54 thumb pieces.
68 triggers.
100 trigger screws.
164 tumblers.
645 tumbler screws.

Parts of Springfield carbine, caliber .45.

102 bands.
332 stocking bands.
26 band springs.
6 band swivels.
4 barrels.
3 breech blocks.
4 breech block caps.
77 breech block cap screws.
6 breech screws.
45 bridles.
49 bridle screws.
7 butt plates.
22 butt plate covers.
187 butt plate screws.
9 cam latches.
232 cam latch springs.
464 ejector springs.
363 ejector spring spindles.
65 ejector spring studs.
85 extractors.
270 firing pins.
109 firing pin screws.
262 firing pin springs.
110 front sights.
20 front sight rivets.
22 guard bows.
14 guard bow nuts.
28 guard bow swivels.
49 guard bow swivel screws.
11 guard bow plates.
24 guard bow plate screws.
121 guard screws.
23 hammers.
40 hinge pins.
80 jointed ramrods.
7 rear sights.

71 rear sight bases.
276 rear sight leaves.
3 rear sight slides.
50 sears.
60 sear screws.
115 sear springs.
50 sear spring screws.
196 side screws.
2 side screw washers.
786 stocks, complete.
89 stocks, wood part.
31 swivel bars.
31 swivel bar rings.
6 swivel bands.
159 tang screws.
10 tip screws.
11 triggers.
43 trigger screws.
3 thumb pieces.
67 tumblers.
131 tumbler screws.

Parts of Sharps' carbine.

1 band.
2 band springs.
1 barrel bushing.
1 barrel stud.
14 bridles.
8 bridle screws.
2 butt plate screws.
5 extractors.
29 firing pins.
6 firing bolt screws.
1 front sight.
2 front guard plates.
2 rear guard plates.
2 hammers.
12 levers.
4 lever catches.
6 lever catch screws.
6 lever catch springs.
6 lever catch spring screws.
6 lever catch spring pins.
27 lever keys.
4 lever key stops.
10 lever key stop pins.
10 lever key stop pin screws.
12 lever key stop springs.
2 lever screws.
27 lever springs.
7 lever spring screws.
1 lock plate.
17 main springs.
7 main spring screws.
5 primer covers.
5 primer cover screws.

2 rear sight bases.
10 rear sight elevating screws.
5 rear sight joint pins.
3 rear sight leaves.
5 rear sight slides.
10 rear sight slide screws.
5 rear sight springs.
15 rear sight spring screws.
14 sears.
7 sear screws.
5 front side screws.
5 rear side screws.
1 slide screw.
2 stock butts.
5 stock tips.
10 stock tip screws.
10 stock butt escutcheons.
2 swivel bars.
2 swivel bar rings.
2 swivel bar screws.
1 front tang screw.
1 rear tang screw.
5 toggles.
1 trigger.
2 trigger screws.
27 tumblers.
42 tumbler screws.
12 tumbler stirrups.
12 tumbler stirrup screws.

Parts of Colt's revolver, caliber .45.

53 back straps.
182 back strap screws.
20 bolts.
65 bolt screws.
377 center pins.
157 center pin bushings.
155 center pin catch screws.
415 center pin screws.
97 ejector springs.
105 ejector heads.
77 ejector rods.
27 ejector rod heads.
27 ejector tubes.
85 ejector tube screws.
119 ejector tube springs.
82 firing pins.
67 firing pin rivets.
5 firing springs.
14 gates.
16 gate catches.
157 gate catch screws.
58 gate springs.
5 gate-latch springs.
3 guards.

127 long guard screws.
152 short guard screws.
34 hammers.
85 hammer screws.
74 hands.
105 hand springs.
147 main springs.
105 main spring screws.
25 sear springs.
5 sear spring screws.
82 sear and stop bolt springs, combined.
72 sear and stop bolt spring screws, combined.
12 stocks.
58 stop bolt screws.
30 triggers.
63 trigger screws.

Parts of Schofield's Smith and Wesson revolver, caliber .45.

20 barrel catches.
25 barrel catch screws.
25 barrel catch springs.
10 base pins.
6 cylinders.
20 cylinder catches.
25 cylinder catch screws.
10 cylinder catch cams.
25 escutcheons.
20 extractors.
25 extractor springs.
25 extractor stems.
25 extractor studs.
25 friction collars.
10 guards.
25 guard screws.
10 hammers.
25 hammer studs.
25 hands.
25 hand pins.
25 hand springs.
25 joint pivots.
25 joint screws.
20 lifters.
28 main springs.
25 main-spring swivels.
25 nuts.
20 pawls.
25 pawl pins.
25 pawl springs.
10 recoil plates.
25 long side-plate screws.
25 short side-plate screws.
5 sights.
25 sight pins.
5 stocks.
25 stock pins.
25 stock screws.

25 strain screws.
25 steady pins.
25 stops.
25 stop pins.
25 stop springs.
25 swivel pins.
13 triggers.
25 trigger pins.
25 trigger springs.
25 trigger-spring pins.

CLASS X—VII.

3,650 canteen corks.
548 canteen corks and chains.
7,950 canteen covers.
4,490 canteen straps.
260 cartridge loops.
20 haversack hooks.
145 saber-belt straps.
125 bridle headstalls.
150 bridle reins.
17,402 brass buckles.
11,782 iron buckles.
69 cincha straps.
1,800 coat straps.
24 couplings for reins.
3,180 crupper rings.
606 curb bits.
70 curb straps.
600 curb-straps and loops.
140 curb strap loops.
1,803 D rings.
4,127 brass foot-staples.
4,129 guard plates.
44¼ gross guard-plate-screw pins.
217 yards girth-webbing, 4 inches wide.
252 yards girth-webbing, 4½ inches wide.
775⅝ yards girth-webbing 7½ inches wide.
8 pieces girth-webbing.
2,060 halter bolts.
612 halter chains.
510 halter headstalls.
3,438 halter rings.
1,980 halter squares.
5,609 halter straps.
108 brass rings.
1,297 iron rings.
100 lariat swivels.
48 saddle-bag studs.
600 shields.
2,267 side-line fasteners.
12 snaps for links.
267 snaps for side-lines.
1,728 spring snaps.
4,076 staples for rings.
240 stirrup hoods.
1,196 yards surcingle webbing, 4 inches wide.

CLASS X—VIII.

3,500 cartridge-bags for 6-pounder gun.
8,280 cartridge-bags for 12-pounder gun.
700 cartridge bags for 12-pounder mountain howitzer.
1,000 cartridge-bags for 24-pounder gun.
600 cartridge-bags for 24-pounder howitzer.
500 cartridge-bags for 32-pounder gun.
200 cartridge-bags for 100-pounder gun.
913 ½-pound cartridge-bags for mountain howitzer.
2,780 cartridge-bags for 3-inch gun.
1,450 cartridge-bags for 4½-inch gun.
500 cartridge-bags for 8-inch converted gun.
1,000 cartridge-bags for 10-inch columbiad.
500 cartridge-bags for 10-inch Rodman.
500 cartridge-bags for 15-inch Rodman.

Tools and material.

3 adzes.
1 adze handle.
52⅝ gallons alcohol.
4 anvils.
14 leather aprons.
2 arbors.
3 augers.
811 awls.
381 awl handles.
42 axes.
172 metallic powder-barrels.
477 wooden powder-barrels.
1 gallon benzine.
201½ pounds beeswax.
47 bits.
208 pounds leather-blacking.
24½ gallons leather-blacking.
421¾ pounds black wax.
1 anvil-block.
1 lead punching block.
51 punching blocks.
1 forge and battery wagon-box.
1 shoeing box.
350 feet pine boards.
24 braces.
6 bath brick.
6 quarts browning material.
324 corn brooms.
12 brushes.
24 dusting-brushes.
10 marking-brushes.
2 oiling-brushes.
155 paint-brushes.
28 sash-brushes.
10 whitewash-brushes.
1 wire-brush.
2 gross buttons.
1 buttress.

1 calipers.
250 toe calks.
35 pounds camphor.
57 tin cans.
45 pounds sperm candles.
1 gross crayon chalk.
3 pounds white chalk.
2 chalk lines.
9 channelers.
240 arm chests.
2 armorer's chests.
59 chisels.
2 chisel handles.
1 chuck.
4 clamps.
42 saddler's clamps.
64 claw tools.
2 boxes cleaning material.
3 clenching irons.
1 clock.
50½ quires crocus cloth.
6,070 pounds bituminous coal.
50 pounds ammoniated copper.
4 collets.
87 compasses.
164⅜ pounds cord.
134 pounds cotton.
3 counter-shafts.
2 card covers.
112 creasers.
4 dies.
3 die stocks.
2 copper discs.
1 lathe dog.
14 gallons Japan drier.
26 pounds patent drier.
1 drift.
41 drills.
2 drill stocks.
2 cooper's drivers.
134 edge tools.
61 pounds emery.
816 quires emery cloth.
40½ quires emery paper.
3 nail extractors.
162 files.
12 file handles.
20 pounds steel filings.
2 straining forks.
2 fullers.
6 powder funnels.
200 gas checks.
15 gauges.
1 carpenter's gauge.
21 gimlets.
10 pounds glue.

50 pounds white glue.
10 gouges.
530 pounds wheel grease.
1 grindstone.
2 groovers.
53 pounds gum-arabic.
197 hammers.
1 hand power.
1 handle for grindstone crank.
3 hangers.
1 hardie.
2 hasps and straps.
2 hasps and staples.
13 claw hatchets.
1 hatchet.
4 hatchet handles.
4 strap hinges.
8,776 horseshoes.
645 pounds horseshoe nails.
31 stitching horses.
1,200 wooden hoops for barrels.
1 housing for pressure plug.
100 pounds band iron.
512 pounds bar iron.
367 knives.
3 drawing knives.
5 gallons lacquer.
22 gallons tar lacquer.
37 pounds lampblack.
1 pound lampwicking.
3 common lanterns.
2 dark lanterns.
23 globe lanterns.
237 pounds lard.
1 hand lathe.
140 feet belt or band leather.
813 sides bridle leather.
22,354 pounds harness leather.
63 locks.
2 sets loopsticks.
1 splitting machine.
53 mallets.
155 pounds marline.
6 powder measures.
1 tape measure, 200 feet long.
52 pounds nails.
13 pounds copper nails.
315 pounds cut nails.
½ pound japanned nails.
1,180 pounds iron nails.
40 pounds saddler's nails.
132 saddler's nails, No.
11,960 needles.
76 cutting nippers.
400 pounds refined niter.
1 collar palm.

10 quires drawing paper.
100 pounds laboratory paper, No. 1.
770 pounds laboratory paper, No. 4.
400 pounds laboratory paper, No. 6.
24 pounds log paper.
58 pounds Manila wrapping paper.
61 pounds stencil paper.
1,035 pounds black paint.
100 pounds green paint.
137 gallons lead-colored paint.
4,225 pounds metallic paint.
2,955 pounds olive paint.
605 pounds red paint.
[illegible]50 pounds red lead.
1,777 pounds white lead.
2 pounds black pepper.
26 pincers.
12 planes.
1,000 feet oak plank.
27 pliers.
7 pokers.
6 pounds leather polish.
1 pot for melting sealing-wax.
5 pounds potash.
112 pounds chlorate of potash.
1 letter-press.
42 pricking carriages.
10 pricking wheels.
13 pritchels.
9 pulleys.
40 punches.
108 hand punches.
72 spring punches.
90 pounds putty.
90 rasps.
24 shoeing rasps.
1 chalk line reel.
222 pounds rivets and burrs.
259 gross brass rivets and burrs.
785 pounds copper rivets and burrs.
31 papers copper rivets and burrs.
158 pounds iron rivets and burrs.
52 riveting irons.
54 rivet-sets.
535 pounds hemp rope.
1,206 pounds Manila rope.
11 rounding irons.
545 pounds rotten-stone.
64 rules, 2-foot.
3,416 sheets sand-paper.
79 sandstones.
14 saws.
1 back saw.
1 hack saw.
4 hack saw blades.
1 hand saw.

2 saw blades.
2 saw sets.
5 scales.
1 counter scales.
19 scissors.
15 pounds scouring material.
2 box scrapers.
218¼ gross brass screws.
116⅔ gross brass screw pins.
15 gross iron screws.
2 pendulum hausse seat screw taps.
69 screw drivers.
2 scribers.
6 scythes.
1 scythe snath.
8 scythe stones.
3 sets.
4 sealing-stamps.
14 pounds sealing-wax.
13 chamois skins.
22 sheep skins.
63 shears.
11 shovels.
6 sickles.
1 sledge.
49 slickers.
96 magazine slippers.
2,315 pounds castile soap.
47 bars castile soap.
37 bars common soap.
20 pounds common soap.
10 pounds solder.
3 spokeshaves.
37 pounds sponge.
7 squares.
2 staples and plates.
60 pounds bar steel.
5 pounds blister steel.
58 pounds cast steel.
200 pounds flowers of sulphur.
4 sets stencils, figure.
4 sets stencils, letters.
110 papers copper tacks.
41 pounds copper tacks.
2 papers cut tacks.
534 papers iron tacks.
683⅝ pounds iron tacks.
140 pounds tallow.
4 taps.
12⅛ barrels tar.
75 thimbles.
724½ pounds shoe-thread.
648 3/16 pounds saddlers' thread.
47 ticklers.
7,420 feet oak timber.
15 pounds tobacco.

7 tongs.
101 sash tools.
10 smith's and saddler's tool-bags.
1 saddlers' tool-case.
57 pounds tow.
314 papers tripoli.
531½ gallons turpentine.
116 pounds twine.
97½ gallons varnish.
1 pound vermilion.
1 bench vise.
2 clamp vises.
4 hand vises.
1 water-cooler.
2 browning wheels.
2 buffing wheels.
2 wheelbarrows.
70 pounds whiting.

APPENDIX C.

Apportionment of ordnance, ordnance stores, &c., for the fiscal year ending June 30, 1878, under sections 1661 and 1667 Revised Statutes United States, and regulations established in conformity therewith.

States and Territories.	No. of Senators and Representatives.	Money value.
Alabama	10	$4,797 85
Arkansas	6	2,878 71
California	6	2,878 71
Colorado	3	1,439 36
Connecticut	6	2,878 71
Delaware	3	1,439 36
Florida	4	1,919 14
Georgia	11	5,277 64
Illinois	21	10,075 49
Indiana	15	7,196 78
Iowa	11	5,277 64
Kansas	5	2,398 93
Kentucky	12	5,757 42
Louisiana	8	3,838 28
Maine	7	3,358 50
Maryland	8	3,838 28
Massachusetts	13	6,237 21
Michigan	11	5,277 64
Minnesota	5	2,398 93
Mississippi	8	3,838 28
Missouri	15	7,196 78
Nebraska	3	1,439 36
Nevada	3	1,439 36
New Hampshire	5	2,398 93
New Jersey	9	4,318 06
New York	35	16,792 48
North Carolina	10	4,797 85
Ohio	22	10,555 27
Oregon	3	1,439 36
Pennsylvania	29	13,913 76
Rhode Island	4	1,919 14
South Carolina	7	3,358 50
Tennessee	12	5,757 42
Texas	8	3,838 28
Vermont	5	2,398 93
Virginia	11	5,277 64
West Virginia	5	2,398 93
Wisconsin	10	4,797 85
Arizona Territory*	3	1,439 36
Dakota Territory*	3	1,439 36
Idaho Territory*	3	1,439 36
Montana Territory*	3	1,439 36
New Mexico Territory*	3	1,439 36
Utah Territory*	3	1,439 36
Washington Territory*	3	1,439 36
Wyoming Territory*	3	1,439 36
District of Columbia	3	1,439 36
Total	396	189,995 00
Freight, &c	....	10,005 00
		200,000 00

*Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

APPENDIX D.

Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1877, to June 30, 1878, under sections 1661 and 1667, Revised Statutes United States.

CLASS I.

2 6-pounder bronze guns.
4 light 12-pounder bronze guns.
6 12-pounder bronze field howitzers.
8 3-inch wrought-iron rifled guns.
2 Gatling guns; caliber .50.
15 Gatling guns, 10 barrels, long; caliber .45.

CLASS II.

4 carriages and limbers for 6-pounder gun.
6 carriages and limbers for light 12-pounder guns.
8 carriages and limbers for 3-inch gun.
16 carriages and limbers for Gatling guns; caliber .45.
2 carriages and limbers for Gatling guns; caliber .50.
4 caissons and limbers for light 12-pounder gun.
4 caissons and limbers for 3-inch gun.

CLASS III.

3 breech-sights 10-pounder Parrott guns.
12 sponge-buckets, iron, for field guns.
16 tar-buckets, iron, for field guns.
20 watering buckets.
6 fuse blocks.
6 fuse cutters.
6 fuse gouges.
8 fuse wrenches.
2 fuse-plug wrenches.
670 feed cases for Gatling gun; caliber .45.
20 gunner's gimlets, field.
49 gunner's haversacks.
12 gunner's pincers.
8 gunner's pouches.
38 handspikes, trail.
42 sets of artillery harness, 2 horses, wheel.
37 sets of artillery harness, 2 horses, lead.
60 artillery whips.
50 lanyards for friction primers.
10 pendulum hausses for light 12-pounder gun.
4 pendulum hausses for 3-inch gun.
6 pendulum hausse seats.
4 pendulum hausse pouches for light 12-pounder gun.
4 pendulum hausse pouches for 3-inch gun.
41 priming wires.
16 prolonges.
24 sponges, woolen, 6-pounder gun.

4 sponge covers, 6-pounder gun.
23 sponge covers, light 12-pounder gun.
8 sponge covers, 12-pounder howitzer.
20 sponge covers, 3-inch gun.
4 sponges and rammers, 6-pounder gun.
3 sponges and rammers, 10-pounder gun.
8 sponges and rammers, light 12-pounder gun.
8 sponges and rammers, 12-pounder howitzer.
24 sponges and rammers, 3-inch gun.
11 paulins, 8 by 10.
34 paulins, 12 by 15.
4 paulins, 20 by 30.
8 gun-covers for long-barreled Gatling gun; caliber .45.
62 thumbstalls.
10 tompions for 3-inch gun.
2 tompions for light 12-pounder gun.
18 tow-hooks.
34 tube pouches.
44 vent covers.
23 vent punches.
4 worms and staves, for light 12-pounder gun.
7 worms and staves, for 3-inch guns.

CLASS IV.

10 6-pounder canister.
166 12-pounder shell.
132 3-inch shot.
124 3-inch canister.

CLASS V.

60 6-pounder shot, fixed.
60 6-pounder case shot.
25 12-pounder shot, fixed.
73 12-pounder shell, fixed.
25 12-pounder case shot.
59 12-pounder canister, filled.
1,000 1-inch ball cartridges, Gatling.
1,000 1-inch canister, Gatling.
408 3-inch shot, fully prepared.
240 3-inch shell, fully prepared.
100 3-inch case shot.
232 3-inch canister, filled.
50 3.67-inch canister, filled.

CLASS VI.

Muzzle-loading.

160 Springfield rifle muskets, caliber .58.

Breech-loading.

3,859 Springfield rifles, caliber .50.
8,791 Springfield rifles, caliber .45.
440 Springfield rifles, cadet, caliber .45.
14 Springfield rifles, officer's model, caliber .45.
186 Springfield carbines, caliber .45.
11 Remington revolvers, caliber .44.
239 Colt's revolvers, caliber .45.

103 Schofield-Smith and Wesson revolvers, caliber .45.
44 officer's swords, with two scabbards.
7 officer's sabers.
112 non-commissioned officer's swords.
274 light cavalry sabers.
313 artillery sabers.
255 bayonets for caliber .50, rifles.
100 bayonets for caliber .45, rifles.

Class VII.

401 sets infantry equipments.
161 haversacks and straps.
4,616 canteens and straps.
1 meat-ration can.
1 knife, fork, and spoon.
200 coat straps.
360 valises.
260 clothing-bags.
210 shoulder-braces.
199 artillery saber belts and plates.
70 carbine slings and swivels.
106 carbine cartridge pouches.
1 cartridge belt.
12 cap pouches.
74 pistol cartridge pouches.
136 pistol holsters.
349 saber belts and plates.
101 saber knots.
157 non-commissioned officer's sword belts and plates.
8,947 steel bayonet scabbards.
150 steel bayonet scabbards, cadet's.
1,068 leather bayonet scabbards.
2,090 cartridge-boxes, caliber .58.
6,680 cartridge-boxes, caliber .45.
1,318 cartridge-boxes, caliber .50.
5,110 gun slings.
9,923 waist belts and plates.
11 combination screw-drivers.
8 spring vises.
23 headless cartridge shell extractors.
1 set horse equipments.
90 curb bridles.
92 cavalry saddles.
177 saddle blankets.
40 spurs and straps, pairs.

Class VIII.

1,030 blank cartridges for 10-pounder gun.
224 blank cartridges for light 12-pounder gun.
1,150 blank cartridges for 3-inch gun.
5,000 buck and ball cartridges, caliber .69.
45,000 elongated ball cartridges, paper, caliber .58.
1,000 rifle ball cartridges, caliber .58 (rim fire).
667,060 rifle ball cartridges, caliber .50.
544,000 rifle ball cartridges, caliber .45.

9,500 carbine ball cartridges, caliber .45.
9,072 Spencer carbine cartridges, caliber .50 (rim fire).
5,076 pistol ball cartridges, caliber .45.
55,000 rifle blank cartridges, caliber .50.
26,000 rifle blank cartridges, caliber .45.
5,750 friction primers.
150 paper fuses, time, assorted.
1 pound quick match.
425 pounds cannon powder.
2,000 pounds mortar powder, new.
200 cartridge bags for 3-inch gun, unfilled.

CLASS X.

6 spare poles.
11 pole pads.
7 pairs pole straps.
6 spare wheels.

Spare parts for Springfield rifle, caliber .50.

33 main springs.
33 sear springs.
50 tumblers.
33 tumbler screws.
11 extractors.
33 ejector springs.
33 cam latch springs.
33 firing pins.
33 firing pin springs.
33 firing pin spring screws.
33 breech block cap screws.
100 rear sights.
35 stocks.
95 ramrods.
100 ramrod stops.

Spare parts for Springfield rifle, caliber .45.

225 tumblers.
13 tumbler screws.
100 triggers.
100 trigger screws.
25 front sights.
25 rear sights.
10 rear sight bases.
20 rear sight base screws.
40 rear sight base springs.
20 rear sight leaves.
40 rear sight slides.
40 rear sight slide springs.
40 rear sight slide spring rivets.
40 rear sight joint pins.
45 thumb pieces.
25 locks, complete.
10 lock plates.
5 guards.
20 guard plates.
20 guard bows.

50 guard bow swivels.
50 guard bow swivel screws.
50 guard bow screws.
65 sears.
13 sear springs.
100 sear spring screws.
125 sear screws.
10 stocks.
20 butt plates.
40 butt plate screws.
65 hammers.
40 tips.
40 tip screws.
50 stacking swivels.
100 gun sling swivels.
100 gun sling swivel pins.
50 bayonet clasps.
50 bayonet clasp screws.
100 band springs.
13 main springs.
25 main spring swivels.
25 main spring swivel rivets.
55 bridles.
175 bridle screws.
65 tang screws.
75 upper bands, complete.
75 lower bands, complete.
50 ejector spring spindles.
63 ejector springs.
10 ejector studs.
10 breech blocks.
20 breech block caps.
13 breech block cap screws.
10 breech screws.
40 hinge pins.
20 cam latches.
13 cam latch springs.
13 firing pins.
13 firing pin springs.
13 firing pin screws.
250 side screws.
150 side screw washers.
3 extractors.

MISCELLANEOUS.

12 pounds lead color paint.
6 pounds black paint.
25 pounds olive paint.
4 pounds wheel grease.
2 boxes cleaning materials.
1 set regimental armorer's tools.
6 pick axes.
6 felling axes.
5 paint brushes.
6 long handled shovels.

APPENDIX E.

Statement of ordnance, ordnance stores, &c., distributed to colleges and universities from July 1, 1877, to June 30, 1878, under section 1225 Revised Statutes United States, as amended by act approved July 5, 1876.

CLASS I.

6 6-pounder bronze guns.
4 3-inch wrought-iron guns.
2 10-pounder Parrott guns.
1 8-inch siege mortar.

CLASS II.

1 8-inch mortar bed.
1 8-inch mortar platform.
4 6-pounder gun carriages and limbers.
6 3-inch gun carriages and limbers.
6 caissons and limbers for 6-pounder guns.
2 caissons and limbers for 3-inch guns.

CLASS III.

1 basket for mortar implements.
1 watering-bucket, leather.
2 fuse cutters.
2 fuse mallets.
1 fuse saw.
1 gunner's gimlet, mortar.
13 gunner's haversacks.
1 gunner's level.
1 gunner's quadrant, brass.
1 gunner's sleeve.
16 handspikes.
22 lanyards for friction-primers.
2 6-pounder pendulum hausses.
2 3-inch pendulum hausses.
2 seats for pendulum hausses.
1 pouch for pendulum hausses.
1 plummet.
1 pointing cord.
2 pointing stakes.
2 priming wires, 8-inch mortar.
10 priming wires, field.
1 shell-hook pairs.
1 scraper for mortar.
1 woolen sponge for 6-pounder gun.
12 sponge covers for 6-pounder gun.
4 sponge covers for 3-inch guns.
2 sponge covers for 8-inch mortars.
12 sponges and rammers, 6-pounder gun.
8 sponges and rammers, 3-inch gun.
2 sponges and rammers, 8-inch mortar.
1 paulin 5 by 5 feet.

4 paulins 12 by 15 feet.
12 thumbstalls.
1 tompion, 8-inch mortar.
12 tube pouches.
2 tube pouches, 8-inch mortar.
10 vent covers, 8-inch mortar.
1 wiper, 8-inch mortar.
1 wrench for mortar-bed.

Class IV.

10 8-inch mortar shells.

Class VI.

50 Springfield rifles, caliber .45.
615 Springfield cadet rifles, caliber .45.
27 non-commissioned-officer's swords, steel scabbards.
10 non-commissioned-officer's swords, leather scabbards.
70 light cavalry sabers.

Class VII.

17 non-commissioned-officer's shoulder belts and plates.
20 non-commissioned-officer's sword belts and plates.
40 saber belts and plates.
665 steel bayonet scabbards.
665 cartridge boxes, caliber .45.
665 waist belts and plates.

Class VIII.

850 blank cartridges for 6-pounder gun.
150 blank cartridges for 10-pounder Parrott gun.
400 blank cartridges for 12-pounder gun.
50 blank cartridges for 8-inch mortar.
3,500 carbine ball cartridges, caliber .50.
8,000 carbine ball cartridges, caliber .45.
3,000 rifle ball cartridges, caliber .50.
1,000 rifle ball cartridges, caliber .45.
1,000 rifle (cadet) ball cartridges, caliber .45.
5,000 rifle and carbine blank cartridges, caliber .50.
9,500 rifle and carbine blank cartridges, caliber .45.
3,900 friction primers.
100 pounds mortar powder, new.

Class X.

50 cartridge bags, unfilled, for 8-inch mortar.

Miscellaneous.

1 broom.
1 maul.

APPENDIX F.

Statement of ordnance stores, &c., distributed to the Territories and States bordering thereon from July 1, 1877, *to June* 30, 1878, *under the joint resolutions of July* 3, 1876, *March* 3, 1877, *and June* 7, 1878.

200 Spencer carbines, caliber .50.
2,100 Springfield rifles, caliber .50.
5,040 Spencer carbine cartridges (rim fire), calibre .50.
105,000 rifle ball cartridges, caliber .50.

APPENDIX G.

Showing stations and duties of the officers of the Ordnance Department on the 1st of October, 1878.

Rank and name.	Duty.
BRIGADIER-GENERAL.	
Stephen V. Benét	Chief of Ordnance.
COLONELS.	
1. P. V. Hagner, brevet brigadier-general.	Commanding the Watervliet arsenal.
2. F. D. Callender, brevet brigadier-general.	Commanding the Augusta arsenal.
3. T. T. S. Laidley, brevet	Commanding the Watertown arsenal, and president of the United States board to test iron, steel, &c.
LIEUTENANT-COLONELS.	
1. J. G. Benton, brevet colonel	Commanding the National Armory, and president of the board to select a magazine-gun for the United States service.
2. J. McAllister, brevet colonel	Commanding the Benicia arsenal.
3. S. Crispin, brevet colonel	Commanding the ordnance agency; president of the ordnance board, and constructor of ordnance.
4. T. J. Treadwell, brevet	Member of the ordnance board.
MAJORS.	
1. T. G. Baylor, brevet colonel	Commanding the New York arsenal, and member of the ordnance board.
2. J. M. Whittemore, brevet	Commanding the Frankford arsenal.
3. A. R. Buffington, brevet	Commanding the Allegheny arsenal.
4. D. W. Flagler, brevet lieutenant-colonel.	Commanding the Rock Island arsenal.
5. A. Mordecai, brevet lieutenant-colonel.	Instructor of ordnance and gunnery, United States Military Academy.
6. S. C. Lyford, brevet lieutenant-colonel.	On duty in the office of the Chief of Ordnance.
7. F. H. Parker, brevet	Commanding the Fort Monroe arsenal, and member of the board to select a magazine-gun for the United States service.
8. J. P. Farley	Commanding the Kennebec arsenal, and member of the board to select a magazine-gun for the United States service.
9. L. S. Babbitt	Chief ordnance officer, Department of the Columbia.
10. W. A. Marye	Assistant, Benicia arsenal.

Stations and duties of officers, &c.—Continued.

Rank and name.	Duty.
CAPTAINS.	
1. I. Arnold, jr., brevet	Commanding the Indianapolis arsenal.
2. J. H. Rollins, brevet	Assistant, Watervliet arsenal (on sick leave of absence for one year from April 1, 1878).
3. C. Comly, brevet	Commanding the San Antonio arsenal, and chief ordnance officer, Department of Texas.
4. J. R. McGinness, brevet major	Commanding the Saint Louis powder depot (on leave of absence till October 23, 1878).
5. G. W. McKee, brevet major	Commanding the Washington arsenal.
6. F. H. Phipps, brevet	Recorder of the ordnance board.
7. J. W. Reilly, brevet	Chief ordnance officer, Military Division of the Missouri.
8. J. A. Kress, brevet major	Commanding the Vancouver arsenal.
9. O. E. Michaelis, brevet	Chief ordnance officer, Department of Dakota.
10. W. Prince, brevet	Sick leave of absence for six months from June 5, 1878.
11. C. E. Dutton	On duty with Powell's geological survey of the Rocky Mountain region.
12. J. G. Butler	Assistant, Watervliet arsenal.
13. C. Bryant	Assistant to the constructor of ordnance.
14. A. L. Varney	Assistant, Watervliet arsenal.
15. J. C. Clifford	Assistant, Rock Island arsenal (temporarily in command of the Saint Louis powder depot).
16. E. M. Wright	Assistant, Frankford arsenal.
17. J. E. Greer	Assistant, National Armory, and recorder of the board to select a magazine-gun for the United States service.
18. J. Pitman	Assistant, Watertown arsenal.
19. Vacancy 20. Vacancy	Act of Congress, June 18, 1878.
FIRST LIEUTENANTS.	
1. C. Shaler	Chief ordnance officer, Department of the South.
2. H. Metcalfe	Assistant, Frankford arsenal.
3. W. S. Starring	Assistant to the constructor of ordnance.
4. C. S. Smith	Assistant, New York agency.
5. S. E. Blunt	Acting assistant professor of mathematics, United States Military Academy.
6. F. Heath	Assistant, Rock Island arsenal.

Stations and duties of officers, &c.—Continued.

Rank and name.	Duty.
FIRST LIEUTENANTS.	
7. D. M. Taylor	Chief ordnance officer, Department of the Missouri, commanding the Fort Leavenworth ordnance depot.
8. D. A. Lyle	Assistant, National Armory, and on special duty experimenting with life-saving apparatus, &c.
9. J. Rockwell, jr	Assistant instructor of ordnance and gunnery, Military Academy.
10. W. B. Weir	Commanding the Cheyenne ordnance depot.
11. J. C. Ayres	Commanding the Fort Abraham Lincoln ordnance depot.
12. M. W. Lyon	Assistant, Allegheny arsenal.
13. C. W. Whipple	Assistant to the constructor of ordnance.
14. A. H. Russell	Assistant, Rock Island arsenal (on sick leave of absence for six months from September 6, 1878).
15. R. Birnie, jr	On duty with the engineer survey west of the one hundredth meridian.
16. I. MacNutt	Assistant, Rock Island arsenal.
ORDNANCE STOREKEEPERS.	
(Not in the line of promotion.)	
E. Ingersoll, major	On duty, National Armory.
W. R. Shoemaker, captain	In charge, Fort Union arsenal.
B. H. Gilbreth, captain	On duty, Watertown arsenal.
E. D. Ellsworth, captain	On sick leave.
W. Adams, captain	On duty, Fort Monroe arsenal.
A. S. M. Morgan, captain	On duty, Rock Island arsenal.
W. H. Rexford, captain	In charge of Fort Yuma ordnance depot.
F. Whyte, captain	On duty, Washington arsenal.
D. J. Young, captain	On duty, Watervliet arsenal.
M. J. Grealish, captain	On duty, Augusta arsenal.

APPENDIX H.

EXPERIMENTS WITH AN ELECTRICAL INTERRUPTER. BY MAJOR ALFRED MORDECAI, ORDNANCE DEPARTMENT, UNITED STATES ARMY, INSTRUCTOR OF ORDNANCE AND GUNNERY AT THE UNITED STATES MILITARY ACADEMY.

(One plate.)

UNITED STATES MILITARY ACADEMY,
West Point, N. Y., December 31, 1875.

This device was first tested by me in February of this year, and was used from time to time with most promising results.

In order to compare this attachment with the Schultz interrupter, I had a series of trials made here very recently by Mr. J. J. O'Reilly, from the Frankford Arsenal, using the interrupter belonging to the chronoscope at that arsenal.

The conditions imposed were that the circumstances under which the trials were made should be as nearly as possible the same for each interrupter.

This was effected by the trials being conducted in pairs in rapid succession, the results being taken with the same battery on one cylinder. The two interrupters were so arranged that a switch would throw one out of and bring the other into operation.

The objects of the experiments were to determine—

First. The time required to set up sustained vibration with each.

Second. The number of vibrations in a second and their uniformity.

Third. The effect of temperature and state of atmosphere on number of vibrations.

Fourth. The effect produced on the number of vibrations—

(*a*) by changing amplitude;
(*b*) by changing length of spring;
(*c*) by changing strength of spring;
(*d*) by changing contact of spring.

Fifth. The effect of altering the strength of the battery.

The results of these experiments are given in the following tables:

FIRST SERIES.—*Schultz Interrupter.*

Trial	1.	2.	4.	5.	6.	7.	8.	9.	3.
Date	October 25, 1875.		October 26, 1875.						
Thermometer, Fahr	71°	75°	75°	70°	70°	70°	70°	70°	55°
Barometer at 32° Fahr	29″.75	29″.83	30″.02	29″.89	29″.89	29″.99	29″.99	29″.99	30″.03
Galvanic battery, No. of cells.	6	6	7	6	9	7	7	7	7
Amplitude of vibration in saw-teeth.	Same as first with Russell.	6	6¼	5	7½	6¼	6¼	6	6¼
Seconds.	Double vibrations.								
1	249.8	249.4	249.8	249.6	249.7	249.6	249.7	249.8	249.8
2	249.7	249.3	249.8	249.6	249.6	249.7	249.7	249.7	249.8
3	249.7	249.5	249.8	249.7	249.6	249.8	249.8	249.7	249.7
4	249.6	249.2	249.7	249.7	249.5	249.7	249.6	249.8	249.8
5	249.6	249.3	249.7	249.5	249.6	249.8	249.65	249.7	249.7
6	249.6	249.6	249.7	249.65	249.5	249.8	249.55	249.5	249.7
7	249.8	249.3	249.7	249.65	249.5	249.7	249.6	249.6	249.7
8	249.75	249.3	249.6	249.6	249.4	249.7	249.5	249.6	249.7
9	249.75	249.1	249.5	249.75	249.45	249.6	249.6	249.7	249.8
10	249.7	249.1	249.6	249.65	249.4	249.6	249.6	249.6	......
11	249.6	249.6	......	......	......	......	......	......	......
12	249.7	......	......	......	......	......	......	......	......
Average	249.69	249.34	249.69	249.64	249.52	249.70	249.63	249.67	249.74
Mean error in one second:									
Double vibration ±	0.0616	0.138	0.074	0.052	0.079	0.06	0.066	0.076	0.048
Second ±	0.00024	0.00055	0.00029	0.0002	0.00032	0.00024	0.00026	0.0003	0.00019

NOTE.—The amplitude of vibration is in all cases expressed in "saw-teeth" of the micrometer scale.

FIRST SERIES.—*Russell Interrupter.*

Trial	1.	2.	4.	5.	6.	7.	8.	9.	3.
Date	October 25, 1875.		October 26, 1875.						
Thermometer, Fahr	71°	75°	75°	72°	72°	74°	74°	74°	55°
Barometer at 32° Fahr	29″.79	29″.83	30″.02	29″.87	29″.87	29″.93	29″.93	29″.93	30″.03
Galvanic battery, No. of cells.	4	6	7	4	6	7	7	7	7
Amplitude of vibration in saw-teeth.	Same as 1st with Schultz.	9½	9¾	8	10	8½	8¾	9	10
Seconds.	Double vibrations.								
1	249.9	249.8	250.1	250.1	250.0	250.1	250.0	249.9	250.2
2	249.9	249.7	250.1	250.0	250.1	250.0	250.1	249.95	250.3
3	250.0	249.8	250.0	250.0	250.0	249.9	249.9	249.9	250.2
4	250.0	249.7	250.0	250.0	250.0	250.0	249.9	249.95	250.2
5	250.0	249.7	249.9	249.9	250.0	249.9	249.9	249.9	250.1
6	249.9	249.7	249.95	249.9	249.9	249.8	249.9	249.8	250.2
7	249.9	249.7	249.95	249.95	249.8	249.9	249.9	249.9	250.2
8	249.8	249.5	249.9	249.9	249.85	249.8	249.8	250.0	250.2
9	250.0	249.6	249.9	......	249.8	249.9	249.8	249.9	250.2
10	249.9	249.7	250.0	......	249.8	249.8	249.8	249.95	......
11	249.8	249.6	......	......	......	......	......	......	......
12	249.9	249.5	......	......	......	......	......	......	......
13	249.9	......	......	......	......	......	......	......	......
14	250.0	......	......	......	......	......	......	......	......
15	249.9	......	......	......	......	......	......	......	......
16	249.8	......	......	......	......	......	......	......	......
17	249.9	......	......	......	......	......	......	......	......
18	250.0	......	......	......	......	......	......	......	......
19	249.8	......	......	......	......	......	......	......	......
20	249.9	......	......	......	......	......	......	......	......
Average	249.91	249.67	249.98	249.97	249.92	249.91	249.9	249.91	250.2
Mean error in one second:									
Double vibration ±	0.054	0.0766	0.06	0.056	0.095	0.07	0.06	0.037	0.022
Second ±	0.00022	0.0003	0.00024	0.00022	0.00038	0.00028	0.00024	0.00015	0.000088

SECOND SERIES.—*Russell Interrupter.*

Trial	1.	5.			4.	6.		
Date	October 27, 1875.							
Thermometer, Fahr	71°	70°	70°	70°	70°	71°.5	71°.5	71°.5
Barometer at 32° Fahr	29''.64	29''.71	29''.71	29''.71	29''.69	29''.74	29''.74	29''.74
Galvanic battery, number of cells	6	6	6	6	6	6	6	6
Kind of spring	No. 1, light.					No. 3, very light.		
Degree of pressure	Light	Light	Medium.	Strong	Light	Light	Medium	Strong.
Amplitude of vibration in saw-teeth	8.5	7	8	9	8.5 or 9	7.5	8.5	9.5
Seconds.	Double vibrations.							
1	250.00	250.40	250.40	250.60	249.90	250.10	250.10	249.9
2	249.95	250.30	250.30	250.50	249.90	250.10	249.90	249.7
3	249.90	250.40	250.30	250.50	249.90	249.90	249.70	249.6
4	249.85	250.20	250.30	250.40	249.90	249.90	249.90	249.7
5	249.90	250.30	250.40	250.40	249.80	249.90	....	249.7
6	249.90	....	250.00	....	249.80	....	....	249.6
7	249.80	....	250.00	....	249.80	....	....	....
8	249.90	....	....	....	249.80	....	....	....
9	249.90	....	....	....	....	....	....	....
10	249.80	....	....	....	....	....	....	....
11	249.85	....	....	....	....	....	....	....
12	249.85	....	....	....	....	....	....	....
13	249.70	....	....	....	....	....	....	....
14	249.90	....	....	....	....	....	....	....
15	249.80	....	....	....	....	....	....	....
16	249.90	....	....	....	....	....	....	....
17	249.85	....	....	....	....	....	....	....
18	249.80	....	....	....	....	....	....	....
19	249.80	....	....	....	....	....	....	....
20	249.90	....	....	....	....	....	....	....
Average	249.86	250.32	250.24	250.48	249.85	249.98	249.90	249.7
Mean error in one second:								
Double vibration ±	0.0525	0.064	0.14	0.064	0.05	0.096	0.01	0.066
Second ±	0.00021	0.00025	0.00056	0.00025	0.0002	0.00039	0.0004	0.00026

SECOND SERIES.—*Russell Interrupter*—Continued.

Trial	2.	3.			4.
Date	October 27, 1875.				
Thermometer, Fahr	72°	60°	60°	60°	70°
Barometer at 32° Fahr	29″.63	29″.67	29″.67	29″.67	29″.69
Galvanic battery, number of cells	6	6	6	6	6
Kind of spring	No. 2, heavy.				
Degree of pressure	Light	Light	Medium	Strong	Light.
Amplitude of vibration in saw-teeth	6	7.5	9.5	10	8.5 or 9
Seconds.	Double variations.				
1	*250.20	249.90	250.95	249.20	249.90
2	*249.80	250.00	251.00	249.10	249.90
3	*250.20	250.05	250.80	248.90	250.00
4	*249.70	250.00	250.90	248.90	250.00
5	*250.10	250.00	250.80	249.20	249.80
6	250.00			248.60	249.80
7	249.80				249.90
8	249.95				249.80
9	249.95				
10	249.90				
11	249.90				
12	249.90				
13	249.90				
14	249.95				
15	249.85				
16	249.95				
17	249.90				
18	249.85				
19	249.85				
Average	249.93	250.00	250.89	248.98	249.87
Mean error in one second:					
Double vibration ±	0.0915	0.04	0.072	0.183	0.07
Second ±	0.000367	0.00016	0.0002	0.00073	0.00028

* Average for five periods, 250.0.

The object of each trial as noted was, in first series:

First trial with each was on different cylinders, batteries different, to compare time, amplitude being the same. Fifteen minutes occupied adjusting Schultz.

Second trial with each taken on same cylinder, battery the same, to compare time and amplitude. One minute occupied changing from Schultz to Russell and adjusting latter.

Fourth trial with each on same cylinder, to determine relative effect on time and on amplitude by increasing strength of battery. One and a half minutes occupied changing from Schultz to Russell and adjusting latter.

Fifth and sixth trials with Schultz on same cylinder, to determine effect on time, on amplitude, and on adjustment by increasing battery. Five minutes required to adjust interrupter after increase of battery.

Fifth and sixth trials with Russell on same cylinder, to determine effect on time, on amplitude, and on adjustment by increasing battery. No adjustment required after increase of battery.

Seventh, eighth, and ninth trials with Schultz on same cylinder, to determine variation in time and in amplitude and adjustment necessary, a pause of ten minutes being allowed between the first and second, and five minutes between second and third. No adjustment required between trials.

Seventh, eighth, and ninth trials with Russell for same purpose as corresponding trials with Schultz. Five minutes between first and second, and ten minutes between second and third. No adjustment required between trials.

Third trial with each interrupter was on the same cylinder to determine effect of change of temperature on time and on amplitude. Two minutes occupied changing from Schultz to Russell and adjusting latter.

In second series:

First and second trials on different cylinders, to compare effect on time and on amplitude, springs of different stiffness being used, battery the same.

Fifth, sixth, and third trials each on separate cylinder, to determine, with springs of different stiffness, effect on time and on amplitude; spring and battery in each set the same, but contact of spring and point on fork varying.

Fourth trials on one cylinder, compared with first and second trials, showing effect on time and on amplitude of different springs when the manner in which they were attached to plate was varied. The spring was held by a screw. In all other trials of both series it was held by three projections.

Before using the Frankford interrupter the one belonging to the instrument here was tried. Four days were spent by Mr. O'Reilly in trying to get it into working order, and then so unsatisfactory was the result that the Frankford interrupter was sent for. This one differed from the former in that the wooden block supporting the beam was replaced by two brass columns. After it had been placed in position but fifteen minutes were occupied in bringing it into adjustment.

The Russell interrupter has been allowed, at different times, to run uninterruptedly for several hours without any attention being given to it. A reduction in the amplitude was found to occur; by a slight turn of the adjusting screw the original amplitude was speedily re-established. After this interrupter had been in operation for eight consecutive hours a hole was found burned through the end of the spring, but the vibration still continued, though not with the original amplitude. The position of the spring in the holder was quickly changed, and the interrupter was again in proper order.

In the preceding tables some discrepancies will be observed which cannot be satisfactorily accounted for: first, the variation in the time, when the temperature of the air was changed (see trials third of first series), is greater for the Russell than for the Schultz; second, the variation of time between the first and second trials with each interrupter, in the first series, is marked, and without cause; third, the three cases recorded in the fifth trial, second series, are very uniform, but do not agree with the time given in the first, second, fourth, and sixth trials, all of which are quite uniform.

In the third trial, where the pressure was "medium" and "strong," the vibration of the fork was undoubtedly affected by the contact of the spring.

Some of the trials were not pursued to an extent sufficient to make the results of value.

The effect on time of vibration, with any interrupter, produced by a great change in the temperature of the air, and consequently of the metal parts of the instrument, is more interesting than useful, as in practice no such variation is liable to occur. The clock being acted upon by such change much more than is the instrument proper, would cause variation in the record. When such tests are made, the clock

should therefore be kept at a uniform temperature, which was not done in the trials in question. It would seem but proper that under all circumstances a more accurate time-piece, as a chronometer, should be employed with an instrument intended to record such minute intervals of time.

From the first series the mean of all the trials with the Schultz interrupter gives the "mean error in one second" as ±0.0888 double vibration, or ±0.00035 second, and the same for the Russell as ±0.08 double vibration, or ±0.00032 second.

These results vary but little from the limit of allowable error established by Captain Prince, Ordnance Department, in the elaborate experiments made by him at the Frankford Arsenal in November, 1871 (Ordnance Notes, No. IV).

If the readings taken in the second and third trials of the first series be discarded, the errors fall much below that given by Captain Prince.

The trials that have been made so far are in some respects only preliminary; but they are, in my opinion, sufficient to prove the value of the interrupter, and that it can, with good advantage, be substituted for the one supplied by Schultz for use with his chronoscope.

The spring noted No. 1 (0″.1 wide) is believed to be the most suitable, though any spring will probably give uniform results. The pressure of the spring against the platinum point should be "light."

The eating away of the spring by the spark, and its roughening berfore perforation occurs, are points readily overcome by moving the spring or by substituting a new one. Ordinarily, the machine would be used for a long time before any wear would be noticeable.

The simplicity of the interrupter, its ready adaptability to any tuning-fork, the impossibility of its getting out of order, and the ease with which it is at any time speedily adjusted, promise to make it of much value.

Irrespective of the construction of this device, most uniform results are obtained by it, with a greater amplitude of vibration than is practicable with the Schultz interrupter, and with much less strength of battery.

Very successful experiments have been made here with an auxiliary pointer attached to the bed of the metal standard *S S* projecting at *r*, by which the middle line is traced whilst the fork is vibrating. This pointer is adjusted so that the fork being at rest, it and the pointer on the fork will describe the same path on the cylinder.

An alteration which might with little labor be made in the chronoscope, but which would render it still more complicated, possibly without commensurable advantage, would be the introduction of a second Ruhmkorff coil, with its battery, by which the clock could record its beats constantly on the cylinder to one side of the sinuous line whilst the rupture of the targets could be noted on the opposite side. This might require the employment of a different translating screw, and a reduction in the number of readings which the cylinder is now capable of containing.

NOTE.—On the completion of the fifth trial of the second series the spring was found to be loose in the holder, one of the projecting pieces being broken; this had to be repaired before the sixth trial.

By this arrangement, a break-circuit chronometer being used, one source of error should be reduced to a minimum.

This interrupter is fully described in the following letter of First Lieut. A. H. Russell, Ordnance Department, United States Army:

SIR: In accordance with your request I submit a description of the electrical interrupter devised by me for the Schultz chronoscope.

The change consists in replacing the detached mercury interrupter now in use by a light metallic spring, which is pressed against the tuning-fork on the inner side of one prong, making the fork its own interrupter when the electrical current is passed through it.

Fig. 1 represents a part of the original machine. The end of the tuning-fork is shown at *M*, and above it the ebonite table *A* insulating the clamps *b b′* and the support *c c′*.

Fig. 2 shows the new device. *B* is a brass plate which is fastened to the table *A* (fig. 1) by the screw *d* working through the slot *g* into the base of the clamp *b* (fig. 1). This screw should have a milled head, as at *d′* (figs. 2 and 3). Riveted or screwed to the plate *B* is an elastic strip, *e*, fitted with a screw as at *f*, or simply with projections as at *f′*, to hold the spring *s*. A screw (*t*) works through the plate *B* against the strip *e*, thereby raising or lowering the end of the latter. By this means the spring *s*, for which a piece of watch-spring may be used, can be pressed against the platinum point *p* fixed on the inner side of the counterpoise *m* of the tuning-fork.

The fork and the spring are connected with the opposite poles of a galvanic battery, and the current is made and broken at *p* by the vibration of the fork.

For adjustment the plate *B* is slipped under the table *A* and fastened by the screw *d*, so that the spring *s* is just out of contact with the point *p*.

Fig. 3 shows the tuning-fork with the new interrupter in position and the connections complete. A thumb-screw (*r*) is attached to the base of the fork for receiving one wire from the battery. The other wire runs about the electro-magnets at *H*, and thence to the thumb-screw *b*. A battery of four Bunsen's cells works the interrupter.

The wires being adjusted, the circuit is completed at *p* by a turn of the screw *t*, and the electro-magnets becoming magnetized draw the prongs apart. This breaks contact at *p*; the fork flies back and continues to vibrate, the contact being made and broken at every vibration.

The advantages of this device over the old interrupter are as follows:

1. The adjustments are exceedingly simple, and they require but little time, while with the detached mercury interrupter they are very delicate and difficult.
2. The manipulation is very simple and rapid, a mere turn of the screw producing vibration.
3. The use of the mercury cup is entirely avoided.
4. Extra electro-magnets for the interrupter are dispensed with, and the strength of the battery can be greatly reduced.
5. The arrangement is cheap and simple, and not easily deranged.

This interrupter has been in constant use for several months, and it has been practically and successfully tested with the machine.

PLATE I.

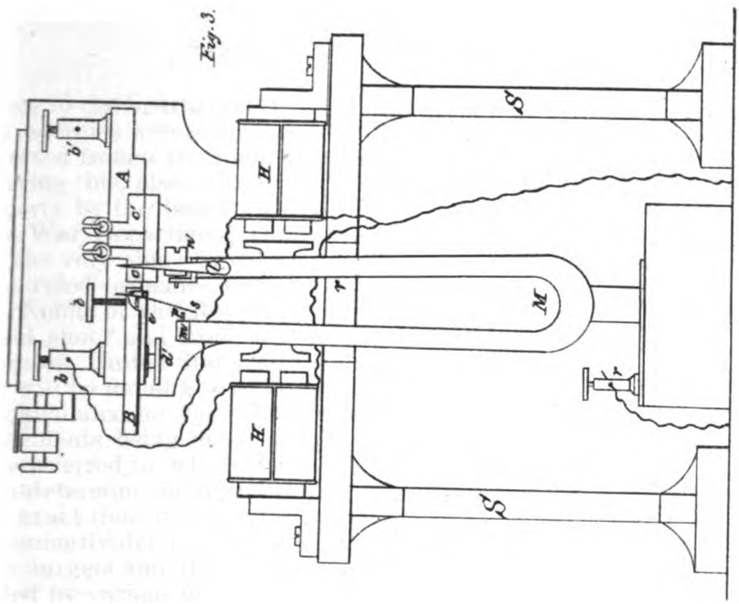


Fig. 3.

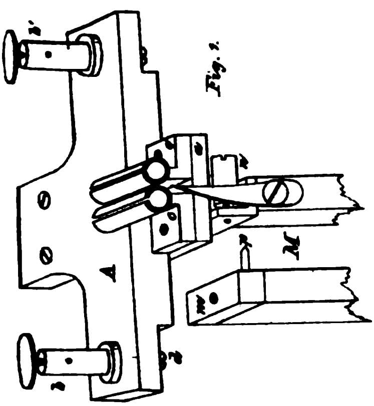


Fig. 1.

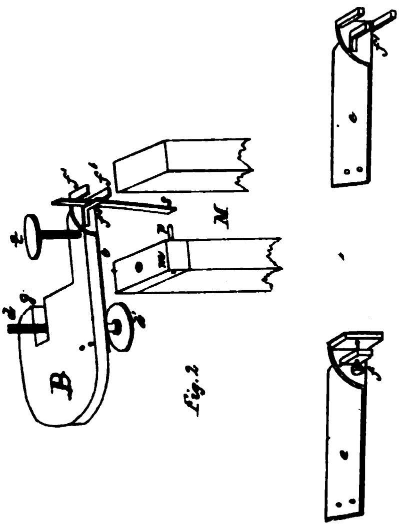


Fig. 2.

Accompanying Appendix H, 1878

APPENDIX I.

THE APPLICATION OF FORMULAS AND GENERAL TABLES TO PROBLEMS IN PRACTICAL GUNNERY. BY CAPT. GEORGE W. McKEE, ORDNANCE DEPARTMENT, UNITED STATES ARMY.

SANDY HOOK, NEW YORK HARBOR,
October 24, 1875.

In obedience to the instructions of the Chief of Ordnance, the following tables of energies were calculated for the 15″ Rodman gun and the 8″ rifle converted from a 10″ Rodman smooth-bore gun.

Accompanying this, also, are some of the formulas used in the preparation of reports by the board on experimental guns, convened under orders of the War Department, October 10, 1874. Some of these were taken from the very able "Text-Book on the construction and manufacture of the rifled ordnance in the British service, from the report of Capt. W. H. Noble, of the Royal Artillery, on the penetration of iron armor by steel shot," and from the "Ordnance and Gunnery" of Lieut. Col. J. G. Benton, United States Ordnance Corps.

Following will be found a brief description of the subject-matter—the cases being calculated for the 8″ and 9″ converted United States rifles; but their statements being made mostly in the language of the "Text-Book," above referred to, which could scarcely be improved on.

In order to determine the initial velocity of a projectile, it is necessary to know the exact time it consumes in passing over a given distance. This is conveniently determined by electricity—the projectile passing through wire targets and thus breaking the circuit—the time of flight being recorded by various ingenious instruments.*

At Sandy Hook the wire targets have an interval of 100′ between them, the first target being 60′ from the muzzle of the gun. The instrument therefore records the precise instant when the shot cuts the first target at sixty (60′) feet, and the second at 160′ from the muzzle of the gun. Hence the time occupied in passing from the first to the second target (a distance of 100′) is known, and by dividing this distance by the time, the velocity of the projectile at a point midway between the targets is found. It will be seen that this is the *remaining* velocity of the projectile at 110′ from the muzzle of the gun. In order to get the *muzzle-velocity*, it is necessary to calculate the loss due to the resistance of the air over this distance of 110′, and the formula employed for this purpose by Capt. W. H. Noble, R. A., has been used in the preparation of tables accompanying reports of these experiments.

This formula is as follows:

$$v = \frac{V}{1 + c\,V\,x} \qquad (1)$$

where†

v = remaining velocity in feet.
V = initial velocity in feet.
x = distance from the muzzle—in feet.
$c = b\,\frac{R^2}{W}$.

* Among those may be mentioned the Schultz chronoscope, Benton's West Point ballistic machine and thread velocimeter, the Le Boulenge chronograph, and the Leurs-Navez machine, as those generally used by American ordnance officers.

† Text-Book on the construction and manufacture of the rifled ordnance in the British service, page 196.

R = radius of the projectile—in feet.
W = weight of the projectile—in pounds.
b = a variable coefficient depending on the form of the shot and velocity of the projectile.

Now the ogival form of head is that used for all service elongated projectiles, and for this form of projectile, and for velocities over 1100′ a second, b may be supposed constant, and for all practical purposes is assumed to be 0.000063.

Suppose, for example, we wish to find the muzzle (or initial) velocity of a 186-pound projectile fired from the United States 8″ converted rifle No. 1, the observed or instrumental velocity being 1368′. In this case we have—

$$\begin{aligned}
\text{Diameter of shot} &= 7.95 \text{ inches.*} \\
R &= 0.33125 \text{ feet.} \\
R^2 &= 0.1097265625 \text{ square feet.} \\
b &= 0.000063. \\
b\,R^2 &= 0.0000069127734375. \\
W &= 186 \text{ pounds.} \\
c = \frac{b\,R^2}{W} &= .0000000371654485 \\
x &= 110 \text{ feet.} \\
v &= 1368 \text{ feet.}
\end{aligned}$$

By transposing the equation

$$v = \frac{V}{1 + c\,V\,x} \qquad (1)$$

we have

$$V = \frac{v}{1 - c\,v\,x} \qquad (2)$$

Substituting the above values of v c and x, we have

$$V = \frac{1368}{1 - .0000000371654485 \times 1368 \times 110} = 1376.$$

Taking equation No. 1 to find the remaining velocity at 1,000 yards, we substitute the values of c V and x ($x = 3000$) and have

$$v = \frac{1376}{1 + .0000000371654485 \times 1376 \times 3000} = 1193.$$

To determine the energy or vis-viva of a projectile at any point of its flight in foot-pounds the old and well-known formula (3)† $E = \frac{W\,v^2}{2\,g}$ is used, in which

W = weight of projectile in pounds.
v = velocity in feet.
g = force of gravity (32.2).

To convert these foot-pounds into foot-tons divide by 2240.

Taking the above example and substituting the values of E v and g, we have

$$E = \frac{186 \times 1376^2}{64.4 \times 2240} = 2441 \text{ foot-tons.}$$

* As the sabot in expanding brings the diameter of that portion of the shot up to 8 inches, R might very properly be made 4 inches; but as the body of the shot still retains its original diameter, and every variety of sabot does not *necessarily* take the grooves well, it was thought safer to take the diameter the shot has before firing.

† g is taken equal to 32.2; its actual value is 32.168557 + for the latitude of New York City. As it enters the divisor, the values of E will therefore be less than the actual energies of the gun—thus basing the subsequent calculations on a liberal, safe, and reliable margin.

Knowing the energy of the projectile at any point of its flight, its *penetrative power* can be determined readily on the principle, based on actual experiment, that the resistance to penetration of a projectile into armor plates varies directly as the diameter or circumference, the total energy being constant.

For instance, if two shot, *of the same weight and moving with the same velocity*, have one a diameter of 10″ and the other only 5″, the resistance to penetration of the former will be twice that of the latter. Therefore, to determine the penetrative power, divide the energy by the number of inches in the shot's circumference.

This gives, at a glance, to artillerists the relative powers of guns in foot-tons per inch of circumference of their projectiles.

Taking the above data at the muzzle

$$R = 3.975 \text{ inches}$$
$$2\,\pi\,R = 24.9757,$$

we find by substituting these values in this expression for energy divided by shot's circumference in inches

$$E^1 = \frac{W\,v^2}{2\,g\,2\,\pi\,R} = \frac{186 \times 1376^2}{64.4 \times 24.9757 \times 2240} = 97.7 \text{ foot-tons.} \qquad (4)$$

Didion's formula for practical use may be briefly summarized as follows:

On page 403, Benton's Ordnance and Gunnery, will be found the equation

$$\rho = A\,\pi\,R^2\left(1 + \frac{v}{r}\right)v^2 \qquad (5)$$

where ρ = general expression for resistance in air.

A = resistance in pounds on a square foot of the cross-section of a projectile, moving with a velocity of one foot.

r = a linear quantity depending on the velocity of the projectile, and for all service velocities=1427 feet.

On page 405 we find:

$$\frac{1}{2\,c} = \frac{\frac{A\,\pi\,R^2}{P}}{g}, \text{ or } 2\,c = \frac{P}{g\,A\,\pi\,R^2} \qquad (6)$$

in which

*A = same as above and for all service spherical projectiles= 0.000514.

g = force of gravity.

R = radius of projectile in feet.

P = weight of projectile in pounds.

c = relative ability of a projectile to overcome the resistance of the air.

On page 415 will be found one of the equations of the trajectory in air, $v = \frac{V}{U}$ (7)

in which v = remaining velocity in feet.

V = initial velocity in feet.

U = a multiplier relating to the velocity, being a function of

*The value of A for elongated projectiles, according to Capt. William Prince, Ordnance Department, is equal to .00037157.

$\frac{x}{c}$ and $\frac{V}{r}$; x representing the horizontal distance in feet, from the muzzle of the gun, of that point of the trajectory where the remaining velocity is desired.

To facilitate the calculations a table of values for U has been computed, and will be found on page 512, Benton's Ordnance and Gunnery. Having, from the previous data, found the values of $\frac{x}{c}$ and $\frac{V}{r}$, look in Table 3 (Values of U for velocities, &c.), on the upper horizontal line, for the next nearest tabular number to the value of $\frac{x}{c}$, and in the left-hand vertical column for the corresponding next nearest tabular number for $\frac{V}{r}$, subtract these tabular numbers from the values of $\frac{x}{c}$ and $\frac{V}{r}$ already found. Divide these differences respectively by 1000 and 500. Subtract the value of $\frac{x}{c}$ from its next horizontal number, and of $\frac{V}{r}$ from its next vertical number, and multiply the quotients obtained above by the remainders.

EXAMPLE.

Find the remaining velocity of a 15″ smooth-bore solid shot, weight 450 pounds, at 400 yards from the muzzle—the muzzle velocity being 1700′, diameter of shot = 14″.90.

Taking equation (6) we have:

$$
\begin{aligned}
{}^{*}g &= 32.2 \\
A &= .000514 \\
\pi &= 3.1416 \\
R &= .620833'
\end{aligned}
$$

$$
\begin{aligned}
\text{Log. } g &= \text{log. } 32.2 = 1.507856 \\
\text{Log. } A &= \text{log. } .000514 = -\,4.710963 \\
\text{Log. } \pi &= \text{log. } 3.1416 = 0.497151 \\
\text{Log. } R &= \text{log. } .620833 = -\,1.792975 \\
\text{Log. } R &= \text{log. } .620833 = -\,1.792975 \\
\hline
& \qquad -\,2.301920
\end{aligned}
$$

$$
\begin{aligned}
\text{Log. } 450 &= 2.653213 \\
& \quad -\,2.301920 \\
\hline
\text{Log. } 2c &= 4.351293 \\
2c &= 22453.99 \\
c &= 11226.99
\end{aligned}
$$

*According to the calculations of Mr. H. A. Sinclair, who worked a large share of these tables, the value of g for New York City is 32.168557 + feet, by subtracting from the value of g, at 45° latitude, the product of .0821 into the cosine of twice the latitude of New York; and by Sabine's method of multiplying the length of the seconds pendulum for New York by π^2, $g = 32$, 160592 +, making a difference of not quite eight-thousandths of a foot between the two methods. These methods are as follows:

$$
\left.\begin{aligned}
g &= 32.1808 - 0.0821 \cos. 2\text{ L} \\
\text{L} &= \text{latitude of New York City.}
\end{aligned}\right\}\text{Ordnance Manual.}
$$

$$
\left.\begin{aligned}
l &= 0.99102557 + 0.00507188 \sin^2 \Phi \\
l &= \text{length of seconds pendulum in metres.} \\
\Phi &= \text{latitude of New York City.} \\
g &= \pi^2\, l = 32.160592 +
\end{aligned}\right\}\text{Sabine.}
$$

The latitude of New York City = 40° 42′ 43″.16 was taken from the United States Coast Survey Charts.

$$\frac{x}{c} = \frac{1200}{11226.99} = 1069$$

$$\frac{V}{r} = \frac{1700}{1427} = 1.1913$$

$$U\ (0.1069;\ 1.1913) = 1.120$$
$$U\ (0.10;\ 1.15) = 1.110$$

$$\frac{69}{1000}\ 116 = .008$$

$$\frac{413}{500}\ 3 = .002$$

$$v = \frac{V}{U} = \frac{1700}{1.120} = 1518.$$

In a very interesting work by the Rev. Professor Francis Bashforth, founded on experiments made with the Bashforth chronograph, there will be found in chapter V, page 67, a description of the general tables appended to the book and instructions for their use. The professor remarks that it will be found sufficient for many practical purposes to neglect the effect of gravity, and treat the motion of a shot as if its path were a straight line, when it is desired to find the loss of velocity, or the time of flight for a limited space, the initial velocity being high; and that, therefore, this method will apply better to pointed elongated shot than to spherical shot, and better to solid shot than to shell of the same external form.

As previously stated, the velocity of a shot is determined while it is describing a given short range—the space in feet being divided by the time in seconds, to get a result which is adopted as the approximate velocity at the middle point. Suppose the path of the shot to be a straight line, and the cubic law* of the resistance of the air sufficiently accurate for all cases in practice—then the method of determining velocity may be shown to be correct for *any range*. Professor Bashforth deduces for the *reduced range* the following expression, $\frac{d^2}{w}s$, and applies it in a very simple table for the convenience of the practical artillerist.

In this expression

d = diameter of a spherical projectile.
w = weight in lbs. of a spherical projectile.
s = distance from muzzle of gun where the remaining velocity is required.

To apply this to the case of a 15″ Rodman solid shot of 450 pounds, moving with an initial velocity of 1700′, at a target 1000 yards distant, we have

$$d = 14''.90$$
$$w = 450 \text{ pounds.}$$
$$s = 3000'$$

$$\frac{d^2}{w}s = .4933 \times 3000 = 1479.9$$

---

*Equation of motion for the cubic law of resistance is $\frac{d^2 s}{d t^2} = \frac{d v}{dt} = -2 b v^3$.—(Bashforth's Motion of Projectiles, page 67.)

Opposite the velocity 1700 in the table* we find 541, and adding 1479.9 to this, we have 2020.9, opposite which, in the same table, we find 1266, which is the required striking velocity.

Now in order to find the penetration of the projectile, at any point of its flight, into backed armor plates,† the following formula of Captain Noble will be found very simple and of great practical value:

$$b = v\sqrt{\frac{W}{4\,\pi\,R\,g\,K}}$$

In which‡ b = penetration in inches.
v = velocity on impact in feet.
W = weight of shot in pounds.
g = force of gravity.
R = radius of shot in feet.
K = a coefficent depending on nature of wrought iron in plate, and nature and form of head of shot.

Supposing the target *to be backed*,§ with our ogival projectile, and taking the same case as before, we have

$$\begin{aligned} K &= 4821480 \\ 4\,\pi\,R &= 4.16262 \\ 4\,\pi\,R\,g &= 134.036364 \\ W &= 186 \text{ pounds.} \\ v &= 1000 \text{ feet.} \end{aligned}$$

Substituting these values in the equation, we have

$$b = 1000\sqrt{134.036364 \times 4821480} = 6.44 \text{ inches.}$$

It should be remarked that this value of b corresponds to a "*work*" which would *just* penetrate a *backed* armor plate when a projectile of 186 pounds weight has a velocity on impact of 1000′. For example, in table No. 1 (see foot-note) we see that a projectile of 180 pounds weight has, at 400 yards (1200′),

A total energy of 2044 foot-tons;
Energy per inch of shot's circumference, 82.6 foot-tons;
And a penetrative power of 7″.69.

This means simply that this "work" on impact of 2044 foot-tons, at 1200′ from the muzzle, is *just* capable of piercing an *unbacked* wrought-iron armor plate having a thickness of 7″.69.

It should be understood that by *penetration* is meant actual *perforation* through the plate, or the power of passing through the plate. In the case of penetration *into* iron plates the term *indent* has been used.

Although experiments conducted for the elucidation of this subject have been extremely limited, on account of the attendant expense, enough

* Table No. 4, appended, taken from "Bashforth's Motion of Projectiles."

† The shot is supposed to be of the best quality of steel and the plate of the best quality of wrought iron.

‡ b is actually the thickness of the plate *in feet*, and the penetration in inches is obtained by multiplying by 12 the value obtained of $v\sqrt{\frac{W}{4\,\pi\,R\,g\,K.}}$

§ Table No. 1 is calculated for *unbacked* plates, and the value of k is assumed equal to 5357200, which Captain Noble takes as the value of this coefficient in the case of unbacked armor plates, when *hemispherical-headed projectiles* are used. The mere statement of this fact will show the large margin of reliability upon which the calculations are based.

has been gathered from native and foreign sources to warrant the following practical conclusions, when the projectiles are fired *direct*, that is to say, when the plane in which the shot moves is perpendicular to the face of the plates.

* First. An unbacked wrought-iron plate will be perforated with equal facility by solid steel shot, of similar form of head, and having the same diameter, provided they have the same vis-viva on impact; and it is immaterial whether this vis-viva be the result of a heavy shot and a low velocity or a light shot and a high velocity, within the usual limits of length, &c.,† which occur in practice.

Second. An unbacked iron plate will be penetrated by solid steel shot of the same form of head, but different diameters, provided their striking vis-viva varies as the diameter, nearly, that is, as the circumference of the shot.

Third. That the resistance of unbacked wrought-iron plates to absolute penetration by solid steel shot, of similar form and equal diameter, varies as the square of their thickness, nearly.‡

Fourth. These experiments have proved that, although in the case of cast iron, a light projectile moving with a high velocity will indent iron plates to a greater depth than a heavier projectile with a low velocity, but equal "work," it is not as necessary that there should be a high velocity when the projectiles are of a hard material, such as *steel* and *chilled* iron, and this result will be much in favor of rifled guns, by enabling them to prove effective with comparatively moderate charges.

It is almost unnecessary to state that, for any *given* thickness of plate, equation 8 may be used to find the velocity corresponding to a "work" which would just penetrate it.

The charge of powder necessary to give a certain number of foot-tons may be approximated to conveniently by using the practical rule for initial velocity, as follows: § For the ordinary purposes of practice, where the weights of the powder and projectile alone vary, *initial velocities may be considered as directly proportional to the square root of the weight of powder, divided by the square root of the weight of the projectile;* or

$$V : V^1 :: \frac{\sqrt{p}}{\sqrt{m}} : \frac{\sqrt{p^1}}{\sqrt{m^1}}$$

EXAMPLE.

The United States 9″ converted rifle, with a charge of 40 pounds Du Pont's hexagonal powder and a projectile weighing 230 pounds, gives a muzzle velocity of 1395′, which corresponds to a work of 6950089 foot-pounds, what charge of powder will raise the "work" to 7.000.000 foot-pounds?

Taking equation (3) $E = \frac{W v^2}{2g}$ and inserting the values of W, g, and E, we find $\frac{230 \times v^2}{64.4} = 7.000.000$ from which $v = 1400$.

* Report on Penetration of Iron Armor Plates. Capt. W. H. Noble, R. A.

† 2.25 diameters is about limit of length.

‡ When plates are of the best quality.

§ Benton's Ordnance and Gunnery, page 387.

The weight of the projectiles being the same (230 pounds) in this case, the proportion

$$V : V^1 :: \frac{\sqrt{p}}{\sqrt{m}} : \frac{\sqrt{p^1}}{\sqrt{m^1}}$$

becomes $$V : V^1 :: \sqrt{p} : \sqrt{p^1}$$

from which $$\sqrt{p} = \frac{V\sqrt{p^1}}{V^1} \qquad (9)$$

Substituting the values of V^1 (1395), V (1400), and p^1 (40),

$$\sqrt{p} = \frac{1400\sqrt{40}}{1395} = 6.3477$$

$$p = 40.29$$

It is understood, of course, that the above method is only marginally correct, and gives the artillerist an idea of *about* what charge of powder to use in "feeling" for velocity or range.

TABLE No. 1.—*Showing the energy and penetrative power in unbacked armor plates of the United States 8″ rifle converted from a 10″ Rodman smooth-bore gun—W. = 180 pounds.*

Range.	Velocity.	Total energy.	Energy per inch of shot's circumference.	Penetration in unbacked armor plates.
	$^*v = \frac{V}{1+cVx}$	$\frac{Wv^2}{2g}$	$\frac{Wv^2}{2g\,2\pi R}$	$b = v\sqrt{\frac{W}{4\pi RgK}}$
Yards.	*Feet.*	*Foot-tons.*	*Foot-tons.*	*Inches.*
0	1360	2308	92.4	8.17
200	1319	2171	86.9	7.92
400	1280	2044	82.6	7.69
600	1243	1928	77.8	7.47
800	1209	1824	73.0	7.26
1000†	1176	1726	69.1	7.07
1200	1145	1636	65.5	6.88
1400	1115	1551	62.1	6.70
1600	1087	1474	59.0	6.53
1800	1061	1405	56.3	6.37
2000†	1036	1339	53.6	6.22
2200	1011	1275	51.0	6.07
2400	988	1218	48.8	5.94
2600	966	1164	46.6	5.80
2800	945	1114	44.6	5.68
3000	925	1068	42.8	5.56
3200	906	1024	41.0	5.44
3400	887	982	39.3	5.33
3600	869	942	37.7	5.22
3800	852	906	36.3	5.12
4000	836	872	34.9	5.02

*Page 69, Bashforth. $\frac{\text{Space in feet}}{\text{Time in seconds}} = \frac{s}{t} = \frac{s}{\frac{s}{V} + bs^2} = \frac{1}{\frac{1}{V} + bs} = v^1 = \frac{V}{1 + Vbs}.$

†Lieut. Col. J. G. Benton, United States Ordnance Corps, comparing Didion's formula with the above, arrives at the following results:

Initial velocity	1360, Noble; 1360,	Ordnance and Gunnery.
1,000 yards	1176, Noble; 1175+,	Ordnance and Gunnery.
2,000 yards	1036, Noble; 1039,	Ordnance and Gunnery.

* **TABLE NO. 2.**—*Giving the force of impact, in foot-tons, of a* 15″ *smooth-bore gun—weight of shot* 450 *lbs.*

Initial velocity and muzzle impact.	Impact.														
	100 yards.	200 yards.	300 yards.	400 yards.	500 yards.	600 yards.	700 yards.	800 yards.	900 yards.	1000 yards.	1100 yards.	1200 yards.	1300 yards.	1400 yards.	1500 yards.
1460 / 6649	6268	5918	5597	5303	5030	4778	4544	4327	4125	3938	3762	3598	3445	3301	3166
1470 / 6741	6351	5995	5667	5366	5088	4831	4593	4373	4168	3977	3798	3632	3476	3330	3193
1480 / 6833	6435	6072	5738	5432	5149	4887	4645	4421	4213	4018	3837	3668	3510	3362	3223
1490 / 6925	6520	6150	5810	5497	5210	4944	4698	4469	4258	4060	3877	3705	3545	3394	3253
1500 / 7019	6606	6228	5880	5564	5271	5001	4751	4519	4304	4104	3915	3743	3580	3428	3285
1510 / 7113	6691	6306	5954	5630	5332	5057	4802	4567	4348	4145	3955	3779	3613	3458	3314
1520 / 7207	6778	6385	6029	5697	5393	5114	4855	4616	4393	4187	3995	3815	3648	3491	3344
1530 / 7302	6865	6465	6099	5764	5455	5171	4908	4665	4439	4229	4035	3852	3682	3524	3375
1540 / 7398	6952	6545	6171	5830	5516	5227	4960	4712	4483	4270	4073	3888	3715	3554	3404
1550 / 7494	7040	6624	6245	5897	5578	5283	5012	4761	4528	4310	4112	3924	3736	3586	3433
1560 / 7592	7128	6704	6319	5965	5640	5341	5066	4811	4574	4355	4151	3961	3784	3619	3463
1570 / 7690	7217	6786	6393	6032	5703	5399	5118	4859	4619	4397	4190	3998	3818	3650	3413
1580 / 7787	7306	6867	6468	6101	5765	5457	5172	4909	4667	4440	4230	4044	3853	3683	3523
1590 / 7886	7395	6949	6541	6170	5828	5514	5225	4958	4711	4482	4269	4071	3886	3714	3553
1600 / 7986	7485	7032	6617	6239	5891	5572	5279	5007	4757	4524	4308	4108	3921	3746	3583
1610 / 8086	7576	7114	6692	6308	5955	5630	5333	5057	4804	4567	4348	4145	3955	3779	3614
1620 / 8187	7667	7198	6768	6376	6018	5689	5386	5106	4849	4609	4387	4182	3990	3810	3643
1630 / 8288	7760	7281	6845	6446	6082	5748	5440	5156	4895	4653	4428	4219	4024	3843	3673
1640 / 8390	7852	7364	6921	6516	6146	5806	5494	5207	4941	4695	4467	4255	4059	3875	3703
1650 / 8493	7945	7449	6998	6587	6210	5865	5548	5257	4988	4738	4507	4292	4093	3907	3734
1660 / 8596	8038	7533	7075	6655	6275	5925	5603	5307	5034	4781	4547	4329	4127	3939	3763
1670 / 8700	8132	7619	7152	6727	6340	5984	5658	5358	5080	4824	4587	4367	4162	3971	3794
1680 / 8804	8227	7704	7230	6799	6404	6044	5713	5408	5127	4868	4627	4404	4197	4004	3824
1690 / 8909	8322	7791	7309	6870	6470	6103	5767	5471	5174	4910	4667	4441	4231	4036	3854
1700 / 9015	8417	7876	7387	6942	6534	6163	5822	5508	5220	4953	4707	4478	4266	4068	3883

* Taken from the United States Naval Ordnance Papers, No. 2.

TABLE No. 3.—*Showing energy and penetrative power in unbacked armor plates of the United States 15″ smooth-bore gun—W. = 450 pounds.*

Distance from muzzle.	Didion. Velocities. $v=\frac{V}{U}$	Bashforth. Velocities. $\frac{d^2}{w}s$	$\frac{Wv^2}{2g}$	Noble. $b=v\sqrt{\frac{W}{4\pi RgK}}$
Yards.	*Feet.*	*Feet.*	*Foot-tons.*	*Inches.*
0	1700	1700	9015	11.796
200	1606	1600	7986	11.102
400	1518	1507	7084	10.457
600	1439	1420	6290	9.853
800	1364	1340	5601	9.298
1000	1295	1266	5000	8.785
1200	1231	1197	4470	8.306
1400	1173	1136	4026	7.883
1600	1117	1081	3645	7.500
1800	1066	1032	3322	7.161
2000	1017	989	3051	6.862
2200	974	950	2815	6.592
2400	930	915	2612	6.349
2600	891	882	2427	6.120
2800	853	851	2259	5.905
3000	817	822	2108	5.704
3200	784	796	1977	5.523
3400	752	771	1854	5.350
3600	723	747	1741	5.183
3800	694	725	1640	5.031
4000	668	704	1547	4.885

* **TABLE No. 4.**—*A general table of values of* $\frac{d^2}{w}s$ *for spherical shot.*

†V.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
F. S.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
50	10649	0620	0592	0563	0535	0506	0478	0450	0422	0394
51	10366	0338	0310	.0283	0255	0228	0201	0174	0147	0120
52	10093	0066	0040	0013	9987	9961	9935	9909	9883	9857
53	9831	9805	9779	9754	9729	9703	9678	9653	9628	9603
54	9578	9553	9529	9504	9480	9455	9431	9407	9383	9359
55	9335	9311	9287	9263	9240	9216	9193	9169	9146	9123
56	9100	9077	9054	9031	9008	8986	8963	8941	8918	8896
57	8873	8851	8829	8807	8785	8763	8741	8719	8698	8676
58	8655	8633	8612	8591	8569	8548	8527	8506	8485	8464
59	8443	8423	8402	8381	8361	8340	8320	8300	8279	8259
60	8239	8219	8199	8179	8159	8139	8120	8100	8081	8061
61	8041	8022	8003	7983	7964	7945	7926	7907	7888	7869
62	7850	7832	7813	7794	7776	7757	7739	7720	7702	7683
63	7665	7647	7629	7611	7593	7575	7557	7539	7521	7504
64	7486	7468	7451	7433	7416	7398	7381	7364	7346	7329
65	7312	7295	7278	7261	7244	7227	7210	7194	7177	7160
66	7144	7127	7110	7094	7078	7061	7045	7029	7012	6996
67	6980	6964	6948	6932	6916	6900	6884	6868	6853	6837
68	6821	6806	6790	6775	6759	6744	6728	6713	6698	6682
69	6667	6652	6637	6622	6607	6592	6577	6562	6547	6532
70	6517	6503	6488	6473	6459	6444	6430	6415	6401	6386
71	6372	6358	6343	6329	6315	6301	6287	6273	6259	6245
72	6231	6217	6203	6189	6175	6161	6148	6134	6120	6107
73	6093	6079	6066	6052	6039	6026	6012	5999	5986	5972
74	5959	5946	5933	5920	5907	5894	5881	5868	5855	5842
75	5829	5816	5803	5790	5778	5765	5752	5740	5727	5714
76	5702	5689	5677	5665	5652	5640	5627	5615	5603	5591
77	5578	5566	5554	5542	5530	5518	5506	5494	5482	5470
78	5458	5446	5434	5423	5411	5399	5387	5376	5364	5352
79	5341	5329	5318	5306	5295	5283	5272	5260	5249	5238
80	5226	5216	5204	5193	5181	5170	5159	5148	5137	5126
81	5115	5104	5093	5082	5071	5060	5049	5038	5027	5017
82	5006	4995	4984	4974	4963	4952	4942	4931	4921	4910
83	4900	4889	4879	4868	4858	4847	4837	4827	4817	4806
84	4796	4786	4776	4765	4755	4745	4735	4725	4715	4705
85	4695	4685	4675	4665	4655	4645	4635	4625	4615	4605
86	4596	4586	4576	4566	4557	4547	4537	4528	4518	4509
87	4499	4490	4480	4471	4461	4452	4442	4433	4423	4414

* Taken from "Bashford's Motion of Projectiles."

† V = velocity; F. S. = feet a second.

TABLE No. 4.—Continued.

V.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
F. S.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
88	4405	4395	4386	4377	4367	4358	4349	4340	4331	4321
89	4312	4303	4294	4285	4276	4267	4258	4249	4240	4231
90	4222	4213	4204	4195	4186	4177	4169	4160	4151	4142
91	4134	4125	4116	4107	4099	4090	4081	4073	4064	4056
92	4047	4039	4030	4022	4013	4005	3996	3988	3980	3971
93	3963	3954	3946	3938	3930	3921	3913	3905	3897	3888
94	3880	3872	3864	3856	3848	3840	3832	3823	3815	3807
95	3799	3791	3784	3776	3768	3760	3752	3744	3736	3728
96	3721	3713	3705	3697	3689	3682	3674	3666	3659	3651
97	3643	3636	3628	3621	3613	3606	3598	3591	3583	3576
98	3568	3561	3553	3546	3539	3531	3524	3516	3509	3502
99	3495	3487	3480	3473	3466	3458	3451	3444	3437	3430
100	3423	3416	3409	3402	3395	3388	3381	3374	3367	3360
101	3353	3346	3339	3332	3325	3319	3312	3305	3298	3291
102	3285	3278	3271	3265	3258	3251	3245	3238	3231	3225
103	3218	3212	3205	3199	3192	3186	3179	3173	3166	3160
104	3154	3147	3141	3135	3128	3122	3116	3109	1303	3097
105	3091	3084	3078	3072	3066	3060	3054	3048	3041	3035
106	3029	3023	3017	3011	3005	2999	2993	2987	2982	2976
107	2970	2964	2958	2952	2946	2941	2935	2929	2923	2918
108	2912	2906	2900	2895	2889	2883	2878	2872	2866	2861
109	2855	2850	2844	2838	2833	2827	2822	2816	2811	2805
110	2800	2794	2789	2784	2778	2773	2767	2762	2757	2751
111	2746	2741	2735	2730	2725	2719	2714	2709	2704	2698
112	2693	2688	2683	2678	2672	2667	2662	2657	2652	2646
113	2641	2636	2631	2626	2621	2616	2611	2606	2601	2596
114	2591	2586	2581	2576	2571	2566	2561	2556	2551	2547
115	2541	2536	2531	2526	2522	2517	2512	2507	2502	2497
116	2492	2487	2483	2478	2473	2468	2464	2459	2454	2449
117	2444	2440	2435	2430	2426	2421	2416	2411	2407	2402
118	2397	2393	2388	2383	2379	2374	2369	2365	2360	2356
119	2351	2346	2342	2337	2333	2328	2323	2319	2314	2310
120	2306	2301	2296	2292	2287	2283	2278	2274	2269	2265
121	2260	2256	2252	2247	2243	2238	2234	2229	2225	2220
122	2216	2212	2207	2203	2199	2194	2190	2185	2181	2177
123	2172	2168	2164	2159	2155	2151	2146	2142	2138	2134
124	2129	2125	2121	2116	2112	2108	2104	2099	2095	2091
125	2087	2082	2078	2074	2070	2066	2061	2057	2053	2049
126	2045	2040	2036	2032	2028	2024	2020	2015	2011	2007
127	2003	1999	1995	1991	1986	1982	1978	1974	1970	1966
128	1962	1958	1954	1949	1945	1941	1937	1933	1929	1925
129	1921	1917	1913	1909	1905	1901	1897	1893	1889	1885
130	1881	1877	1873	1869	1865	1861	1857	1853	1849	1845
131	1841	1837	1833	1829	1825	1821	1817	1813	1809	1806
132	1802	1798	1794	1790	1786	1782	1778	1774	1770	1766
133	1763	1759	1755	1751	1747	1743	1739	1736	1732	1728
134	1724	1720	1716	1713	1709	1705	1701	1697	1694	1690
135	1686	1682	1678	1675	1671	1667	1663	1660	1656	1652
136	1648	1645	1641	1637	1633	1630	1626	1622	1618	1615
137	1611	1607	1603	1600	1596	1592	1589	1585	1581	1578
138	1574	1570	1567	1563	1559	1556	1552	1548	1545	1541
139	1537	1534	1530	1526	1523	1519	1516	1512	1508	1505
140	1501	1497	1494	1490	1487	1483	1479	1476	1472	1469
141	1465	1461	1458	1454	1451	1447	1444	1440	1437	1433
142	1429	1426	1422	1419	1415	1412	1408	1405	1401	1398
143	1394	1391	1387	1384	1380	1377	1373	1370	1366	1363
144	1359	1356	1352	1349	1345	1342	1338	1335	1331	1328
145	1324	1321	1318	1314	1311	1307	1304	1300	1297	1293
146	1290	1287	1283	1280	1276	1273	1270	1266	1263	1259
147	1256	1253	1249	1246	1242	1239	1236	1232	1229	1225
148	1222	1219	1215	1212	1209	1205	1202	1199	1195	1192
149	1189	1185	1182	1179	1175	1172	1169	1165	1162	1159
150	1155	1152	1149	1145	1142	1139	1135	1132	1129	1126
151	1122	1119	1116	1112	1109	1106	1103	1099	1096	1093
152	1090	1086	1083	1080	1077	1073	1070	1067	1064	1060
153	1057	1053	1051	1047	1044	1041	1038	1034	1031	1028
154	1025	1022	1018	1015	1012	1009	1006	1002	999	996
155	993	990	987	983	980	977	974	971	968	964
156	961	958	955	952	949	945	942	939	936	933
157	930	927	924	920	917	914	911	908	905	902
158	899	895	892	889	886	883	880	877	874	871
159	868	864	861	858	855	852	849	846	843	840
160	837	834	831	828	825	822	818	815	812	809
161	806	803	800	797	794	791	788	785	782	779
162	776	773	770	767	764	761	758	755	752	749
163	746	743	740	737	734	731	728	725	722	719
164	716	713	710	707	704	701	698	695	692	689
165	686	683	680	677	674	672	669	666	663	660
166	657	654	651	648	645	642	639	636	633	630
167	628	625	622	619	616	613	610	607	604	601
168	598	596	593	590	587	584	581	578	575	572

TABLE No. 4.—Continued.

V.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
F. S.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
169	569	567	564	561	558	555	552	549	546	544
170	541	538	535	532	529	526	524	521	518	515
171	512	509	506	504	501	498	495	492	489	487
172	484	481	478	475	472	470	467	464	461	458
173	456	453	450	447	444	442	439	436	433	430
174	428	425	422	419	416	414	411	408	405	402
175	400	397	394	391	389	386	383	380	377	375
176	372	369	366	364	361	358	355	353	350	347
177	344	342	339	336	333	331	328	325	322	320
178	317	314	311	309	306	303	301	298	295	292
179	290	287	284	282	279	276	273	271	268	265
180	263	260	257	255	252	249	246	244	241	238
181	236	233	230	228	225	222	220	217	214	212
182	209	206	204	201	198	196	193	190	188	185
183	182	180	177	174	172	169	166	164	161	158
184	156	153	150	148	145	143	140	137	135	132
185	129	127	124	122	119	116	114	111	108	106
186	103	101	98	95	93	90	88	85	82	80
187	77	75	72	69	67	64	62	59	57	54
188	51	49	46	44	41	39	36	33	31	28
189	26	23	21	18	15	13	10	7	5	3

*TABLE No. 5.—*A general table of values of* $\frac{d^2}{w}s$ *for ogival-headed shot.*

†V.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
F. S.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
50	19604.0	19542.0	19480.2	19418.6	19357.2	19296.1	19235.2	19174.6	19114.3	19054.3
51	18994.6	18935.1	18875.8	18816.7	18757.8	18699.1	18640.7	18582.6	18524.6	18466.8
52	18409.2	18351.9	18294.9	18238.0	18181.3	18124.8	18068.5	18012.5	17956.7	17901.1
53	17845.7	17790.6	17735.6	17680.8	17626.2	17571.9	17517.8	17463.9	17410.1	17356.5
54	17303.2	17250.1	17197.2	17144.4	17091.8	17039.4	16987.1	16935.0	16883.1	16831.5
55	16780.2	16729.1	16678.1	16627.2	16576.5	16526.0	16475.7	16425.6	16375.6	16325.8
56	16276.2	16226.9	16177.7	16128.6	16079.6	16030.8	15982.2	15933.8	15885.6	15837.6
57	15789.8	15742.1	15694.6	15647.2	15600.0	15552.9	15506.0	15459.3	15412.7	15366.3
58	15320.1	15274.0	15228.1	15182.3	15136.7	15091.2	15045.9	15000.7	14955.7	14910.9
59	14866.2	14821.7	14777.3	14733.1	14689.0	14645.1	14601.3	14557.7	14514.2	14470.8
60	14427.7	14384.8	14341.9	14299.1	14256.4	14213.8	14171.3	14129.0	14086.9	14045.0
61	14003.3	13961.7	13920.2	13878.9	13837.6	13796.4	13755.3	13714.4	13673.7	13633.2
62	13592.8	13552.4	13512.2	13472.1	13432.2	13392.4	13352.7	13313.1	13273.7	13234.4
63	13195.2	13156.1	13117.3	13078.5	13039.8	13001.2	12962.8	12924.5	12886.3	12848.2
64	12810.2	12772.3	12734.6	12697.0	12695.5	12622.1	12584.8	12547.6	12510.6	12473.7
65	12436.9	12400.2	12363.7	12327.2	12290.8	12254.5	12218.3	12182.3	12146.4	12110.6
66	12074.9	12039.3	12003.9	11968.5	11933.2	11898.0	11863.0	11828.1	11793.2	11758.4
67	11723.7	11689.1	11654.7	11620.4	11586.2	11552.1	11518.1	11484.2	11450.4	11416.7
68	11383.0	11349.4	11316.0	11282.7	11249.5	11216.3	11183.3	11150.4	11117.5	11084.7
69	11052.0	11019.4	10987.0	10954.6	10922.3	10890.1	10857.9	10825.9	10794.0	10762.2
70	10730.5	10698.9	10667.4	10635.9	10604.5	10573.2	10542.0	10510.9	10479.9	10448.9
71	10418.0	10387.2	10356.5	10326.0	10295.5	10265.1	10234.8	10204.6	10174.4	10144.3
72	10114.3	10084.4	10054.6	10024.9	9995.2	9965.6	9936.1	9906.7	9877.4	9848.1
73	9818.9	9789.8	9760.8	9731.9	9703.0	9674.2	9645.5	9616.9	9588.3	9559.8
74	9531.4	9503.1	9474.9	9446.7	9418.6	9390.6	9362.6	9334.7	9306.9	9279.2
75	9251.6	9224.1	9196.6	9169.2	9141.8	9114.5	9087.3	9060.2	9033.1	9006.1
76	8979.2	8952.4	8925.7	8899.0	8872.3	8845.7	8819.2	8792.8	8766.4	8740.1
77	8713.9	8687.7	8661.6	8635.6	8609.7	8583.8	8558.0	8532.3	8506.0	8480.9
78	8455.3	8429.8	8404.4	8379.0	8353.7	8328.5	8303.3	8278.2	8253.2	8228.2
79	8203.3	8178.5	8153.7	8129.0	8104.3	8079.7	8055.2	8030.8	8006.4	7982.0
80	7957.7	7933.5	7909.3	7885.2	7861.1	7837.1	7813.2	7789.3	7765.5	7741.7
81	7718.0	7694.4	7670.8	7647.3	7623.8	7600.4	7577.0	7553.7	7530.5	7507.3
82	7484.2	7461.1	7438.1	7415.1	7392.2	7369.4	7346.6	7323.9	7301.2	7278.6
83	7256.0	7233.5	7211.1	7188.7	7166.3	7144.0	7121.8	7099.6	7077.5	7055.4
84	7033.4	7011.4	6989.5	6967.6	6945.8	6924.0	6902.2	6880.5	6858.9	6837.3
85	6815.8	6794.4	6773.0	6851.6	6730.3	6709.0	6687.8	6666.6	6645.5	6624.5

*Taken from "Bashforth's Motion of Projectiles." †V = velocity; F. S. = feet a second.

TABLE No. 5—Continued.

V.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
F. S.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
86	6603.5	6582.5	6561.6	6540.7	6519.9	6499.1	6478.4	6457.7	6437.1	6416.5
87	6395.9	6375.4	6355.0	6334.6	6314.2	6293.9	6273.7	6253.5	6233.3	6213.2
88	6193.1	6173.1	6153.1	6133.2	6113.3	6093.4	6073.6	6053.8	6034.1	6014.4
89	5994.8	5975.2	5955.7	5936.2	5916.7	5897.3	5877.9	5858.6	5939.3	5820.0
90	5800.8	5781.6	5762.5	5743.5	5724.5	5705.6	5686.7	5667.9	5649.2	5630.5
91	5611.8	5593.2	5574.7	5556.2	5537.7	5519.3	5500.9	5482.6	5464.4	5446.2
92	5428.1	5410.0	5392.0	5374.1	5356.2	5338.3	5320.5	5302.8	5285.1	5267.5
93	5249.9	5232.4	5215.0	5197.6	5180.2	5162.9	5145.7	5128.5	5111.4	5094.3
94	5077.3	5060.4	5043.5	5026.6	5009.8	4993.0	4970.3	4959.6	4943.0	4926.5
95	4910.0	4893.6	4877.3	4861.0	4844.7	4828.5	4812.4	4796.3	4780.3	4764.4
96	4748.5	4732.7	4716.9	4701.2	4685.5	4669.9	4654.4	4638.9	4623.5	4608.1
97	4592.8	4577.6	4562.4	4547.3	4532.2	4517.2	4502.3	4487.4	4472.6	4457.8
98	4443.1	4428.5	4413.9	4399.4	4384.9	4370.5	4356.2	4342.0	4327.8	4313.6
99	4299.5	4285.4	4271.4	4257.5	4243.7	4230.0	4216.4	4202.8	4189.3	4175.8
100	4162.4	4149.1	4135.9	4122.8	4109.7	4096.7	4083.8	4070.9	4058.1	4045.3
101	4032.6	4020.0	4007.5	3995.0	3982.5	3970.1	3957.8	3945.6	3933.5	3921.4
102	3909.5	3897.7	3886.0	3874.3	3862.7	3851.2	3839.8	3828.5	3817.3	3806.1
103	3795.0	3784.0	3773.0	3762.1	3761.2	3740.4	3729.6	3718.9	3708.3	3697.7
104	3687.2	3676.8	3666.4	3656.1	3645.8	3635.6	3625.5	3615.5	3605.5	3595.6
105	3585.8	3576.1	3566.5	3556.9	3547.3	3537.8	3528.4	3519.1	3509.8	3500.6
106	3491.4	3482.3	3473.2	3464.2	3455.2	3446.3	3437.5	3428.7	3419.9	3411.1
107	3402.4	3393.8	3385.2	3376.7	3368.1	3359.6	3351.2	3342.8	3334.4	3326.0
108	3317.7	3309.5	3301.3	3293.1	3284.9	3276.7	3268.6	3260.5	3252.4	3244.3
109	3236.3	3228.4	3220.4	3212.5	3204.5	3196.6	3188.7	3180.9	3173.1	3165.3
110	3157.5	3149.7	3141.9	3134.2	3126.5	3118.7	3111.0	3103.3	3095.6	3087.9
111	3080.3	3072.8	3065.2	3057.6	3050.1	3042.5	3035.0	3027.5	3020.0	3012.6
112	3005.1	2997.7	2990.3	2982.9	2975.5	2968.1	2960.8	2953.4	2946.1	2938.7
113	2931.4	2924.1	2916.8	2909.6	2902.4	2895.2	2888.1	2880.9	2873.7	2866.6
114	2859.4	2852.3	2845.2	2838.1	2831.0	2823.9	2816.9	2809.8	2802.8	2795.8
115	2788.6	2781.8	2774.9	2767.9	2761.0	2754.0	2747.1	2740.2	2733.3	2726.5
116	2719.6	2712.8	2705.9	2699.1	2692.3	2685.5	2678.7	2672.0	2665.2	2658.5
117	2651.7	2645.0	2638.3	2631.6	2625.0	2618.3	2611.6	2605.0	2598.4	2591.8
118	2585.2	2578.6	2572.1	2565.5	2558.9	2552.4	2545.8	2539.3	2532.8	2526.3
119	2519.8	2513.4	2506.9	2500.4	2494.0	2487.5	2481.1	2474.7	2468.3	2461.9
120	2455.5	2449.1	2442.8	2436.4	2430.1	2423.8	2417.4	2411.1	2404.8	2398.5
121	2392.2	2386.0	2379.7	2373.5	2367.3	2361.0	2354.8	2348.6	2342.4	2336.2
122	2330.0	2323.9	2317.7	2311.6	2305.5	2299.3	2293.2	2287.1	2281.0	2274.9
123	2268.8	2262.7	2256.7	2250.7	2244.6	2238.6	2232.6	2226.6	2220.6	2214.6
124	2208.6	2202.6	2196.7	2190.7	2184.8	2178.8	2172.9	2166.9	2161.0	2155.1
125	2149.2	2143.3	2137.5	2131.6	2125.8	2119.9	2114.1	2108.2	2102.4	2096.6
126	2090.8	2085.0	2079.2	2073.4	2067.6	2061.9	2056.1	2050.4	2044.7	2038.9
127	2033.2	2027.5	2021.8	2016.1	2010.5	2004.8	1999.1	1993.5	1987.8	1982.2
128	1976.5	1970.8	1965.2	1959.6	1954.0	1948.4	1942.8	1937.2	1931.7	1926.1
129	1920.5	1915.0	1909.4	1903.9	1898.4	1892.8	1887.3	1881.8	1876.3	1870.8
130	1865.3	1859.8	1854.4	1848.9	1843.5	1838.0	1832.6	1827.2	1821.7	1816.3
131	1810.9	1805.5	1800.1	1794.7	1789.3	1783.9	1778.5	1773.1	1767.8	1762.4
132	1757.0	1751.7	1746.3	1741.0	1735.7	1730.4	1725.1	1719.8	1714.5	1709.2
133	1703.9	1698.6	1693.4	1688.1	1682.9	1677.6	1672.4	1667.1	1661.9	1656.7
134	1651.4	1646.2	1641.0	1635.8	1630.6	1625.4	1620.2	1615.0	1609.9	1604.7
135	1599.5	1594.4	1589.2	1584.1	1578.9	1573.8	1568.7	1563.5	1558.4	1553.3
136	1548.2	1543.1	1538.0	1533.0	1527.9	1522.8	1517.8	1512.7	1507.7	1502.6
137	1497.6	1492.5	1487.5	1482.5	1477.4	1472.4	1467.4	1462.3	1457.3	1452.3
138	1447.3	1442.3	1437.3	1432.4	1427.4	1422.4	1417.5	1412.5	1407.6	1402.6
139	1397.7	1392.7	1387.8	1382.9	1377.9	1373.0	1368.1	1363.1	1358.2	1353.3
140	1348.4	1343.5	1338.6	1333.7	1328.8	1323.9	1319.0	1314.1	1309.3	1304.4
141	1299.5	1294.7	1289.8	1284.9	1280.1	1275.2	1270.4	1265.6	1260.8	1255.9
142	1251.1	1246.3	1241.5	1236.6	1231.8	1277.0	1222.2	1217.4	1212.6	1207.8
143	1203.0	1198.2	1193.4	1188.7	1183.9	1179.1	1174.4	1169.6	1164.9	1160.2
144	1155.4	1150.7	1145.9	1141.2	1136.4	1131.7	1126.9	1122.2	1117.5	1112.7
145	1108.0	1103.3	1098.6	1093.9	1089.2	1084.5	1079.8	1075.1	1070.4	1065.8
146	1061.1	1056.4	1051.7	1047.1	1042.4	1037.7	1033.1	1028.4	1023.7	1019.1
147	1014.4	1009.8	1005.1	1000.5	995.8	991.2	986.6	981.9	977.3	972.7
148	968.0	963.4	958.8	954.1	949.5	944.9	940.3	935.7	931.1	926.5

TABLE No. 5—Continued.

V.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
F. S.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
149	921.9	917.3	912.7	908.1	903.5	898.9	894.3	889.7	885.1	880.6
150	876.0	871.4	866.9	862.3	857.8	853.2	848.6	844.1	839.5	835.0
151	830.4	825.9	821.3	816.8	812.2	807.7	803.2	798.6	794.1	789.5
152	785.0	780.5	775.9	771.4	766.9	762.3	757.8	753.3	748.7	744.2
153	739.7	735.2	730.7	726.2	721.7	717.2	712.7	708.2	703.7	699.2
154	694.7	690.2	685.7	681.2	676.8	672.3	667.8	663.3	658.8	654.4
155	649.9	645.4	640.9	636.5	632.0	627.5	623.1	618.6	614.2	609.7
156	605.3	600.8	596.4	591.9	587.5	583.0	578.6	574.1	569.7	565.2
157	560.8	556.4	551.9	547.5	543.0	538.6	534.2	529.7	525.3	520.9
158	516.4	512.0	507.6	503.1	498.7	494.3	489.9	485.5	481.1	476.7
159	472.3	467.9	463.5	459.1	454.7	450.3	445.9	441.5	437.1	432.7
160	428.3	423.9	419.5	415.1	410.7	406.4	402.0	397.6	393.2	388.9
161	384.5	380.1	375.8	371.4	367.1	362.7	358.3	354.0	349.6	345.3
162	340.9	336.5	332.2	327.8	323.5	319.1	314.8	310.4	306.1	301.7
163	297.4	293.1	288.7	284.4	280.0	275.7	271.4	267.0	262.7	258.4
164	254.0	249.7	245.4	241.0	236.7	232.4	228.1	223.8	219.5	215.2
165	210.9	206.6	202.3	198.0	193.7	189.4	185.1	180.8	176.5	172.3
166	168.0	163.7	159.5	155.2	150.9	146.7	142.4	138.2	134.0	129.7
167	125.5	121.3	117.0	112.8	108.6	104.3	100.1	95.9	91.7	87.5
168	83.3	79.1	74.9	70.7	66.5	62.3	58.1	53.9	49.8	45.6
169	41.4	37.2	33.1	28.9	24.8	20.7	16.5	12.3	8.2	4.1
170	0.0									

APPENDIX K.

MANUFACTURE OF LEATHER. BY FIRST LIEUT. D. A. LYLE, ORDNANCE DEPARTMENT, UNITED STATES ARMY.

(Six plates.)

BENICIA ARSENAL, CAL.,
March 20, 1876.

The chemical combination of elastin and gelatine, the two principal constituents of the skins of animals, with tannin or tannic acid, forms leather.

Elastin, or the horny matter of the skin, is the most important constituent, and is "perfectly insoluble in cold or boiling water; also, in ammonia, acetic acid or alcohol." Tannic acid is the only acid which gives a precipitate with the neutral solution.

Gelatine.—This substance is generated from the cellular tissue by the action of hot water.

With tannic acid or infusion of nut-galls gelatine gives a copious, whitish, curdy precipitate, which coheres on stirring to an elastic mass quite insoluble in water, and incapable of putrefaction. Tannic acid is the only acid that gives a precipitate with a solution of gelatine. It does so even when the solution is exceedingly dilute.

Tannic acids or tannins.—"These substances constitute the astringent principles of plants, and are widely diffused in one form or other through the vegetable kingdom. Tannin is a slightly yellowish, friable, porous mass, having no tendency to crystallization. It is very soluble in water, less so in alcohol, and very slightly soluble in ether. It reddens litmus, and possesses a pure astringent taste, without bitterness."

Dilute tannic acids are used for tanning purposes, and are simply infusions of ground oak-bark, hemlock-bark, sumach, valonia, or some other astringent vegetable matter.

The principle of tanning.—This may be stated as follows: Take the skin of an animal, remove from it the hair, fat, loose flesh and other impurities, and immerse it in a dilute solution of tannic acid; the cellular and elastic tissues will gradually combine with that substance, as it penetrates toward the interior, and will form a compound perfectly insoluble, and which will completely resist putrefaction; this compound is leather.

The hides tanned on this coast are generally divided into *two* classes, "slaughtered" hides, or those fresh from the abattoirs, and "salted" hides, or those which have been salted in order to preserve them from putrefaction until they reach the hands of the tanner. Very few dry hides are tanned here. It is said that the "slaughtered" and "salted" hides make better and smoother leather than dry ones, and are more easily and quickly tanned. Tanners here also state that the leather they make from dry hides is inferior to that made from the same stock in the Eastern States, but that the leather made from wet hides on this coast is superior to the corresponding Eastern manufacture. The process of preparing leather from the crude skin—as practiced by tanners on the Pacific coast—comprises *three* departments, which are almost entirely distinct from one another, viz:

The operations of.............. {
1. The beam-house.
2. The tannery.
3. The currying-shop.
}

1. THE BEAM-HOUSE.

The green and salted hides are brought here first, and are put to soak in vats filled with soft water for about three days, to soften them and to dissolve and remove the salt. The hides thus freshened are placed in vats ($7' \times 8' \times 5'$ = size) containing milk of lime (*i. e.*, quick-lime, slightly air-slacked + water), where they remain about nine days. They are then taken from the lime-vats, cut in halves and "beamed," which operation consists in removing the hair, adhering flesh, earth, &c., with the fleshing-knife. The beam of the beam-house differs from that of the currying-shop, as will be seen hereafter. It is made of thick planks, is semi-cylindrical in shape, with its axis making an angle of about 45° with the floor; the convex side is uppermost, and the higher end, against which the workman holds the skin by pressing against it with his body and legs while he manipulates it, is farthest from the vats. After being scraped and fleshed upon this beam the skins are trimmed. The refuse trimmed off is barreled and sold to the glue-factories for glue stock, and the hair is washed, dried, sacked, and sold for the plasterer's use. The horns and tails are removed by the slaughterer. The hides are here divided into three classes: 1st, for sole-leather—this comprises the heaviest, thickest and best hides; 2d, for harness-leather—these hides are selected for their size, uniform thickness, and freedom from "brand marks," gashes and holes; 3d, for light leather—all those not included in the two former classes.

The skins intended for harness and light leather are next milled in clean soft water for about fifteen minutes to remove the lime and to soften them. They are then bated in a strong solution of hen-manure. This lixivium, or bate, is made by putting one bushel of hen-manure in vats half filled with cold soft water. The manure-vats are $8' \times 5' \times 4'$, and will contain one hundred sides. These vats are cleaned and fresh liquor put in once in two months. In moderately warm weather the sides are left in these for one or two days; in cool weather more time is required. On removal from the manure-vats the sides are washed, stoned, and worked over (scraped on both sides) very carefully on the beam, and all short hairs (new growth), earth and lime removed, leaving the skins soft, pliant, and ready for the absorption of the tanning principle. Sole-leather is never either milled or bated, but is washed and stoned. Cold water only is used in the beam-house.

This ends the beam-house work.

2. THE TANNERY.

Tanning.—The sides, when brought from the beam-house to the tannery, are first placed in the stringers (or vats, $9' \times 8' \times 5'$) and so tied up as to hang lengthwise in the pits. Seventy sides are put in each vat. There they hang in a weak ooze or infusion of oak-bark for seven days. They are then handled daily for about five days more. Handling is taking them out into the air, smoothing them out, sometimes rubbing them to remove ridges and wrinkles, and returning them to their former position in the stringers. Each day that they are handled the strength of the infusion is increased a little.

Layers.—They are now ready to be put in the layers or lay-aways, so called because here the sides are laid away for some time. There are four of these large vats, designated as the first, second, third and fourth layers.

First layer.—The mode of doing this is as follows: First, if the vats

be empty, a thin stratum of ground oak-bark is spread over the bottom of the vat; upon this a skin is laid flat, with the flesh side down, and covered with a layer of ground bark, upon which a second skin is placed, and so on until the vat is filled. A thick stratum of oak-bark is spread over the top and a weak tan-liquor is pumped in till the pit is full Second, if the vat already contains the ooze, a stratum of dry pulverized bark is strewn upon the surface of the liquor, a side placed upon this, then a second layer of bark and another side, and so on, alternating until the vat is filled; the whole sinking slowly in the liquor as the weight is superadded. If the mass does not sink readily, it is trodden down by the feet of the workmen. The flesh side is always placed downward to avoid scratching the grain when removing from the vat with the hook. The sides remain in the first layer about eight days.

Up to this point the operations pursued with the three classes (sole, harness and light leather) have been identical; but from this stage they are somewhat divergent, and will be treated separately.

I. *Sole-leather.*

Second layer.—The sides intended for sole-leather, upon being removed from the first layer, are put down in the same manner in the second layer, but with a strong infusion of bark-liquor, where they are left for eighteen days, and then taken out.

Third layer.—They are placed in third layer as in preceding layers, except that here they are subjected to the action of a very strong liquor, and remain for twenty-five days.

Fourth layer.—The position of the sides in this layer is the same as in the others, but the vat contains the strongest liquor that can be made, to which is added a solution, made by boiling together gambier and valonia in water for an hour (proportions: 1 pound gambier + 1 pound valonia to each side of leather). In this decoction the sides remain four weeks. They are then taken out, and the tanning is completed.

II. *Harness-leather.*

The process of tanning harness-leather is the same as for sole leather until the sides are taken out of the first layer. From this stage those sides intended for harness-leather are treated separately.

Second layer.—In this the sides are stratified in medium liquor, and remain eighteen days.

Third layer.—Then they are put down in the third layer in strong tan-liquor for twenty-five days, after which they are taken out, and the tanning is finished.

III. *Light-leather.*

All sides intended for light leather, on coming out of the first layer, are skived, split, and shaved. By these operations the unfinished leather is hardened. It is next milled in weak tan-liquor for about fifteen minutes, to soften and render it porous enough to imbibe the tannin from the ooze, and it is put in the handlers with a strong liquor for ten days. It is now fully tanned.

3. THE CURRYING-SHOP.

I. *Sole-leather currying.*

After tanning, the sole-leather is soaked in a weak solution of tan-liquor for twenty-four hours, the object being to take out of the surface

of the sides a little of the strong tanning material previously absorbed in the vats of the fourth layer, thus rendering them of a lighter appearance. (Upon this light color depends the selling quality of the leather, buyers preferring light, bright-tinted sides.) After this the sides are taken out and washed with soft water, vigorously applied with split or bamboo brooms, and are then piled up for two days under cover to allow the water to drain off. It is necessary, in order to preserve the light appearance of the leather, that it be kept in a close, dark room and free from currents of air, as the slightest wind impinging upon it after coming out of the tan-vats turns it to a deep brown color.

The sides are next treated to a coat of polar oil, applied with a brush or swab, and are hung up to dry in a cold, dark, close room for eight days. When dry they are taken down, sprinkled with water, and piled in the rolling-room for twenty-four hours. The sides are then rolled under great pressure by a brass roller driven by steam-power, after which they are again hung up for twelve hours to dry. When dry, they are taken down, and either the weight is stamped upon each side, or they are put up in rolls of ten sides each and the total weight stamped upon the rolls. The time occupied in preparing sole-leather for market is 117 days from the date that the green hides entered the beam-house.

II. *Harness-leather currying.*

After tanning, the sides for harness-leather are half dried to enable them to be worked easily. They are skived, and afterward milled in an aqueous solution of sumach for about twenty minutes. One pound of sumach to each side of leather is used in this solution. The sides are then scoured, slicked, and stoned on the grain side, and scoured and slicked on the flesh side, to remove superfluous moisture, glutinous substances, and to stretch them. After these operations have been performed the leather is half dried, stretched, and set by the vigorous use of the slicker upon the scouring table, with the grain side down. It is now stuffed with a mixture of neat's-foot oil and tallow (proportions, $\frac{1}{3}$ tallow + $\frac{2}{3}$ neat's-foot oil), applied with a stiff hair brush to the flesh side, and hung up for a week to dry.

Staining.—The sides are taken down and stained on the grain side with a solution of logwood and sal soda (proportions for 100 sides=10 pounds sal soda + 15 pounds logwood + water), applied with a hair brush.

Blacking.—They are also blacked on the grain side with a decoction of iron-rust and vinegar, put on with a hair brush, after which they are rubbed with hard tallow to give a polished appearance when finished. The currier then sets the sides on the table with the stock-stone, removes moisture and tallow with a steel slicker, and glasses them over with a plate-glass slicker to smooth them and to produce a fine grain. They are next treated with a coat of hot stuffing ($\frac{1}{3}$ neat's-foot oil + $\frac{2}{3}$ tallow), applied with a swab made of lamp-wicking. The leather is now ready to be hung up in the drying-room, where it remains thirty-six hours, when it is taken down, slicker-whitened on flesh side, trimmed, the grease slicked off the grain side, then rubbed with a dry brush to improve the grain, and finally the grain side is given a smooth finish by polishing it off with a woolen cloth.

III. *Light-leather currying.*

a. Bridle-leather.—This is split to required thickness in the splitting-machine, and then curried and finished in the same manner as harness-leather.

b. Collar-leather.—This variety of leather is split, and undergoes the same operations as harness-leather, except that it is stuffed with rosin-oil and is not so carefully finished.

c. Buff leather.—This is very light, and made to imitate calfskin. On being taken from the first layer it is split, shaved carefully, brushed well with water and returned to the tan-vats for about ten days. When taken out it is treated the same as harness and bridle leather, until the process of buffing is reached; that is, the leather is scoured, dried for one and one-half hours, dampened, set on a table, slicked, stuffed with neat's-foot oil, dried, and the grease removed by the slicking-machine. The grain is buffed off the skin until it is very thin; it is then trimmed and blacked in the same manner as for harness-leather. Then a thin layer of neat's-foot oil is spread on the table, and the leather set on this with a glass slicker, flesh side down. This stretches and smooths it, after which it is hung up to dry for twenty hours, taken down and oiled on the flesh side; the object of this being to render the leather supple and to make it break up finely (fold easily) as possible. It is next bruised on the flesh side with a graining-board to soften and render it more pliable, then it is smoothed off with a slicker to remove oil and other impurities.

Sizing.—The leather is now coated with a paste made of flour, soap, beeswax, linseed-oil, and water. Curriers differ somewhat in the proportions of these ingredients. A good size is made as follows: 2 gallons paste = 1 quart flour + ⅓ pound soap, either brown or castile + 2 ounces beeswax + 1 pint linseed-oil, + sufficient water to make the paste of proper consistency. This preparation is applied to the grain side with a sponge. It is then glassed till smooth, and treated with a mixture of gum-shellac and paste (proportions, 1 gallon gum-shellac in thin solution + 1 quart of the above-mentioned sizing); this is rubbed on with a sponge as before. The leather is now hung up in a drying-room heated by steam-pipes, in order to dry the gum coating.

d. Grain leather.—This is split, scoured, and hung out in the open air until nearly dry, when it is run through a pebbling-machine, which stamps a fine grain on the grain side. It is then stuffed on the flesh side with a mixture of ⅔ polar oil and ⅓ tallow, hung up, dried for two or three days, and then blackened same as harness-leather. Each side is now passed through the slicking-machine to remove grease and the grain raised with the graining-board. It is then set on a marble or hard-wood table, grain side down, and swabbed with a coat of neat's-foot oil; after which it is hung up to dry for about twelve hours, taken down and boarded two ways (diagonally) on the grain side, turned and boarded on flesh side to make it pliable, slicked to remove all black spots, turned again and boarded lengthwise up and down the grain side, and finished with a coat of gum-shellac to give a polish.

e. Wax leather.—The preparation of this leather is the same as that of buff leather until the process of stuffing is reached. Then fifteen sides are put in the mill, together with a quantity of grease, at the rate of 2 pounds to each side (proportions, ⅔ neat's-foot oil + ⅓ tallow), and milled for twenty-five minutes; then they are set on a table with a little neat's-foot oil. A coating of the same oil is applied to the grain side, and the sides are hung up to dry for two days, more or less, depending upon the weather. After drying they are whitened, stoned on grain side in the jack, trimmed and boarded two ways at right angles to each other. They are now ready for blacking. A coating, composed of ¼ pound lampblack + 5 gallons soft soap, is applied to the flesh side with a brush; the sides are then glassed in the jack and sized by putting on a paste with a sponge (same paste as used for buff leather), then hung up

for seven or eight days. When dry they are glassed on the flesh side and finished with a coat of paste and gum, as prescribed for buff leather. In wax leather, it should be observed that a body of black is laid on and rubbed into the flesh side, while in grain leather the black is merely a stain on the grain side.

f. Polish-leather or polish-pebble.—This variety is made to imitate goatskin, and is split, scoured and manipulated in the same manner as grain leather up to and including the operation of stuffing. It is then set on a table without oil, which stretches and renders it smooth, dried for twenty-four hours, blacked the same as harness-leather, after which it is run through a fine pebbling-machine to make the grain as small as possible. A coating of blood and harness-blacking (proportion, $\frac{1}{4}$ blood + $\frac{3}{4}$ blacking) is put on to give it a good polish; it is then dried for twelve hours, boarded two ways (at right angles), passed under the jack, where it is polished with a lignum-vitæ slicker, receiving a pressure of about two hundred and fifty pounds in this machine. Six minutes suffice to polish a side. After this it receives another coat of blood and blacking, is dried, boarded two ways (at right angles), bruised on flesh and polished. Lastly, a thin coating of linseed-oil is applied to the grain side, which deadens the glossy appearance and gives the surface a more uniform polish.

g. Oil pebble-leather. This variety is treated in the same manner as polish-leather, except that it is stuffed with neat's-foot oil alone. It is then pebbled in machine (jack), boarded by hand to improve the grain, set on the table with a little oil in order to smooth and stretch it, dried, and again grained by hand. Finally, the leather receives a coat of "French finish" (a compound of glue, blood, and ammonia). Some curriers coat only with warm oil.

h. Trunk-leather.—This leather is split, scoured, dried and set on a table with a stone and slicker, a little oil being used. It is hung up and dried for two days, then stoned on the flesh side in the jack to remove the oil and to give it a uniform color. The leather is now polished on the grain side with a lignum-vitæ slicker, the object being to give it a light-reddish appearance.

i. Splits.—These are the thin pieces shaved from the flesh side of all "light leathers" by the splitting-machine. Having a market value, they are prepared for sale as follows: They are milled in weak tan-liquor for fifteen minutes to break up the hard, gristly grain and to soften them, then placed in vats containing strong bark-liquor for three weeks, taken out, washed, and hung upon poles until dry enough to be split by the machine. The thickness of the splits is governed by the buyer's order. After splitting they are milled as before and replaced in the tanning-vats for three or four days. They are milled for the third time for fifteen minutes in a solution of hot gambier (proportion, 2 ounces gambier to each split + 15 gallons soft water). After this process they are scoured on grain side, slicked off, stuffed with polar oil, partially dried, the oil slicked off, whitened, trimmed, and treated with a coat of thin sizing on the flesh side. The size is that used for buff leather, except that the water is replaced by a solution of quercitron bark and alum (proportions, solution = 1 pound alum to 10 gallons strong decoction of quercitron bark). This gives a yellow color. The splits are next blacked and sized on the grain side (same blacking and sizing used as for wax leather), and hung up to dry for twelve hours, then glassed on both sides with the glassing-jack, laid on a table and treated to a coat of neat's-foot oil on the flesh side. After the oil is absorbed, they are fin-

ished with an application of gum-shellac and paste, the same as that used for buff leather.

j. Mixed leather.—In this division of light leather are included all those which require some peculiar treatment in tanning.

Skirting.—This variety receives the same treatment as harness-leather up to and including scouring, after which the sides are dipped in vats containing an aqueous solution of sumach (proportions, $\frac{3}{4}$ pound sumach to each side of leather + water), which is heated by steam until the temperature is raised to the proper height. In this solution they are handled twice, remaining in the vats the first time about ten minutes, and the second time about half an hour; they are then put down in the same solution and left over night; when removed they present a very light color, which is preserved by drying slowly in a dark place. Dampening them occasionally with water causes them to dry more uniformly. A saturated solution of oxalic acid, to which is added a small quantity of sulphuric acid, is applied to give them a still lighter color. Then they are set on the table with a very little oil, and dried slowly in a dark place for about eight days, taken down, trimmed, and rubbed over with a cloth. The action of the sulphuric acid thickens the leather, but does not improve it.

Latigo leather.—The thinnest hides are selected for this variety in the beam-house, where they are treated in the same manner as harness-leather, except that they are bated more. In tanning, the sides are put in a vat containing a solution of 1 pound alum + $\frac{1}{2}$ pound cutch + $\frac{1}{2}$ pound salt to each side, and remain eight days. The sides are now dried on poles, dampened, and then stuffed in the mill with $1\frac{3}{4}$ pounds stuffing to each side (proportions stuffing = $\frac{2}{3}$ polar oil + $\frac{1}{3}$ tallow), remaining twenty minutes. After this they are set on the grain side with a stock-stone, given a coat of neat's-foot oil, and hung up to dry. The drying must be done as quickly as possible, and should not extend beyond forty-eight hours, in order to prevent the salt coming to the surface. When dry they are trimmed, stoned on the flesh side in the jack, and boarded two ways diagonally.

Lace leather.—This leather is tanned in the same manner as latigo leather, but, instead of being stuffed, it is stoned out on a table to make the grain smooth and buffed on a beam with a currier's knife. It is then stuffed in the mill with about 1 pound cold neat's-foot oil to each side, taken out, slicked and dried. It dries quickly, the grain being buffed off allows the air to penetrate it readily. When dry it is trimmed and soft-boarded to make it pliable, treated with a coat of hot tallow applied on the grain side. This application still further softens it, prevents the salt from coming out, and gives it the appearance of being oil-tanned. Lace-leather is often called alum-leather.

Bellows-leather.—The sides for this variety are put in a weak ooze in the stringers for about two weeks, taken out, washed, partially dried, and split in the splitting-machine. They are then milled in alum liquor for fifteen minutes to break up the grain and gristle, put down in the alum-vat for two or three days, taken out and treated in the same manner as lace or alum leather, except that less grease is used; and, lastly they are trimmed, stoned in the jack, boarded two ways (diagonally), and bruised on the flesh side to make them pliable. But little oil should remain in the sides when finished, else they will soon rot.

Belting, or belting-leather.—This variety is usually tanned to order, and for it the largest hides are selected. They are prepared, tanned, and curried in the same manner as harness-leather, except that on coming out of the first layer they are trimmed, cutting off the cheeks, shanks,

and bellies. These pieces or trimmings are tanned separately, receiving the same treatment as sole-leather, except that only one-half the time is occupied in tanning. When finished, they are known to the trade as "offal," and are used for the insoles of shoes. The parts used for belting are dried, cut into strips of the required size, soaked in water until quite pliable, placed in a stretching-machine and subjected to a tensile strain, varying according to the width of the strips. About 2,500 pounds tensile force is applied to a belt 10″ wide.

Calfskins.—In the beam-house these receive the same treatment as light leather. They are tanned in medium liquor, and in the handlers only, remaining about two weeks, as they are too thin to put in the layers. When taken out they are skived, and, if necessary, the thick parts are passed through the splitting-machine. After this they are put in weak liquor for two weeks, taken out, milled in a solution of sumach (¼ pound sumach to each skin), scoured and dried. Calfskins are always stuffed in the mill, as this causes the neat's-foot oil and tallow to permeate the skin, while in hand-stuffing the tallow is left on the surface. The skins are next set on a table with a stock-stone, coated with neat's-foot oil, dried, whitened on flesh side with a steel slicker, trimmed, grain side passed under the stoning-jack, boarded two ways (at right angles), blacked and finished in the same manner as wax leather.

CLASSIFICATION.

In order to produce good tannages, the stock of hides should be uniform in weight, substance, and condition. For these conditions to obtain, a careful assorting of the hides must be resorted to before sending them to the lime-vats or sweat-pits, and again repeated at the different stages until they arrive at the handlers.

If the hides in a pack vary much, those of medium thickness may be tanned perfectly, while the thick ones will be under and the thin ones over tanned.

The same inequality will be found in packs when different kinds of stock (*i. e.*, fresh slaughter, green-salted, pickled, dry-flint, or dry-salted hides) are worked together. The latter fault is apt to be the trouble at small tanneries, as they cannot wait to obtain a pack of *one kind* of hides, and consequently throw together a miscellaneous stock. Uniformity of result in such a heterogeneous mass is an impossibility. The very best leather is made by those tanners who use one quality of material for one kind of leather. Few can afford to do this. Heretofore, the rules for classifying hides have been arbitrary and exceedingly vague; the individual opinion of the dealer guided in most cases. At the meeting of the National Convention of Tanners and Dealers in Hides and Leather, held at the Centennial Exhibition in Philadelphia, in October, 1876, the following rules were unanimously adopted for the object of securing a uniform method of classifying hides. "These rules will control the action of the whole trade until otherwise ordered."

RULES FOR THE CLASSIFICATION OF HIDES.

RULE 1.—All hides having one or more grubs shall be thrown out and classed as damaged.

RULE 2.—All hides and skins cut and scored on the flesh shall be thrown out and classed as damaged.

RULE 3.—All hides for currying purposes having one or more brands shall be thrown out and classed as No. 2 hides.

RULE 4.—All hides sold for sole leather having more than one brand shall be thrown out and classed as No. 2 hides.

RULE 5.—All harness hides visibly damaged by hook or horn marks on the grain shall be classed as No. 2 harness hides.

RULE 6.—In the vocabulary of this trade one letter, figure, or mark constitutes a brand on a hide, and cattle-raisers, in their own interest, are requested to make their brands of one letter or mark, as small as possible, and so located upon and down the leg as to produce the least possible injury to the hide.

RULE 7.—The above rules concerning cuts, scores, grubs, and brands shall be applied to all transactions in dried hides as well as to those that are fresh or salted; also to imported as well as to domestic hides.

RULE 8.—All calfskins shall have the sinews taken out, or proper tare allowed for the same; the minimum weight of untrimmed skins shall be 8 pounds and the maximum weight shall be 15 pounds. This classification to be applied strictly to calfskins, with no application to long-hair summer kips, which shall not be considered calfskins. Trimmed calfskins, with heads off, shall be 1½ pounds less weight; veal-kips shall be classed as plump; milk-calfskins, 15 to 25 pounds, in the season shall be classed as short-hair kip.

RULE 9.—A green-trimmed hide is a hide clear of horns, bones of all kinds, flesh, sinews, blood, manure, or other offal.

RULE 10.—Green-salted hides shall be considered in good merchantable condition when the same are fully cured or preserved with salt, and well cured of their animal juices, and free from all salt and superfluous wet in the hair or on the flesh, or so made by proper tare, when bought and sold.

RULE 11.—Any watered hide, or one which has any material put upon it except salt, for strictly curing purposes, shall not be considered in a merchantable condition, and all sales of hides made in such condition shall be considered fraudulent, unless the condition be made known to the purchaser previous to the sale.

RULE 12.—Hides cut at the throat shall be classed as unmerchantable, provided the gash extends more than one-fourth across the hide.

MILLING.

In many tanneries it is the custom to mill the hides after they have been through the process of "sweating." This operation is most injurious, as it "fulls" in the hair, and removes the gelatine which is now nearly soluble in water. This wasted gelatine should rightfully go to make leather when combined with tannin.

LIMING.

The lime-vats should be large, and long enough to handle the hides whole. The lime causes the thin parts of the hides to contract more than the thick. The hides should never be cut in halves until after liming, else an irregular back line will be the result, which will lead to loss in cutting where long strips are required. This is especially important in belting and harness leather. Lime loosens the hair, saponifies the fat, and distends the fiber. Some contend that lime carries off the gelatine and albumen of the skin.

High-limed leather is loose in texture, weighs light, wears out rapidly, and the subsequent fermentation in the bate after liming increases the evil.

USE OF VITRIOL, OR SULPHURIC ACID.

Tanners are generally anxious that thin leather should appear thick when finished. To accomplish this they resort to a solution of sulphuric acid in which the sides are immersed for a certain number of hours, the length of time depending upon the strength of the liquor.

The acid is usually added to the ooze in the handlers. This acid distends and injures the fiber, and if not removed from the grain will leave directly beneath it a dark-brown stratum, which in sole-leather is very objectionable to manufacturers who employ machine instead of hand labor in removing the grain from the soles of boots and shoes, as it leaves the soles dark and less attractive to the buyer. The gallic acid of the

vats leaves a similar stratum, but it can easily be removed by other acids. The vitriol stain cannot be counteracted, and exposure to the weather renders its existence more and more apparent. It is used to neutral ize the lime as well as to "plump" the fiber. Where judiciously used, the whole substance of the hide is slightly swelled, and the grain is not injured. It should not be used with "sweat" leather. Thick hides will stand more sulphuric acid than thin ones, and so of the corresponding parts of the same hide.

The use of this acid has become general, and so injudicious has been its application that it has called forth the condemnation of manufacturers of leather goods.

Vitriol-raised leather treated with weak liquors produces the poorest quality of leather; the grain being poor and harsh to the touch, the fiber coarse and woolly.

COLORATION.

1. *Color due to tanning materials.*

Almost every tanning material stamps its own peculiar quality on the leather subjected to its action. The physical characteristics usually affected are the color, scent, toughness, or the power of resisting moisture or decay. The coloring matter in some excellent tanning materials prevents their use, since a deep-rooted custom requires both upper and sole leather to be of a yellowish fawn color, while anything that interferes with this tint is objected to by buyers.

Oak bark.—Oak bark imparts firmness and solidity to leather, while other barks give a greater or less degree of softness.

Nothing indicates the superiority of oak bark used in tanning so much the peculiar excellence of sole-leather.

This bark gives a lighter color, and, it is generally assumed, a better leather than hemlock. The most desirable kinds of oak bark are procured from the "rock oak" or "chestnut oak" (*Quercus prinus monticola*), the "yellow chestnut oak" (*Q. castanea*), and the black oak (*Q. tinctoria*.) The latter is called "yellow oak" by tanners on account of the yellow color it imparts to leather, and is distinguished from all other species by the rich yellow or orange color of its inner bark. It constitutes the quercitron bark of dyers and tanners. The bark of the white oak (*Quercus alba*) contains less tannin than either of the above, but produces a beautiful leather.

Red oak (*Q. rubra*) gives a leather whose section has a dirty red color, but this color is not as fresh looking as that of hemlock-tanned.

Hemlock (*Abies canadensis*).—Hemlock is rich in tannin, and is little, if any, inferior to oak for tanning purposes. By some it is regarded as being not only equal to, but better than the much-lauded oak bark. The dark reddish color it imparts to the leather has always militated against its popularity as a tanning material. Tanners divide the hemlock used for tanning into *white* and *red*—the difference is probably not specific, but dependent upon climate, soil, and situation.

Gambier or *Terra japonica* (*Uncaria gambir*) is the most important substitute for bark. It gives a very dark color (reddish brown) and is generally used in conjunction with black-oak bark.

Cutch and *Catechu* (*Acacia catechu*) are similar in their properties to the above. They tan rapidly, but the leather produced is light, spongy, permeable to water, and of a dark reddish fawn color.

Valonia (acorn cups of *Quercus Ægilops*) is a good tanning material,

but expensive, and needs to be protected from moisture to preserve its useful properties. Leather tanned with this material is said to be harder and less permeable to water than that made with oak bark.

Divi divi (from pods of *Cæsalpina coriaria*) generally makes a porous leather, having a brown or dark brownish-red color.

Larch (*Larix americana*) bark gives a very inferior leather to that prepared with either oak or hemlock.

Willow (from various species of the Order *Salicaceæ*) bark gives a peculiar yellow color to leather, but leaves it very flexible.

Sumac (*Rhus coriaria* or *glabra*) makes a light-colored leather; it is generally used in connection with bark.

Divi divi and sumac liquors soon ferment, especially in warm weather.

Bleaching.—"Slaughter hemlock leather tanned with liquors of moderate strength * * * will come out with a color that is between the lemon and orange; if to this we add the warm sumac process, we get a color so nearly a light lemon or a flesh color as to meet the requirements sought in the best oak leather." "For fine work, the buff is superior to most pure oak tannages, for these have a 'sickly white' tint which soils more readily than the hemlock or union tannages bleached as indicated."

"This bleaching process is particularly serviceable on calf and all grain-finished leathers, including harness and bridle. No purely hemlock tannage will 'take the blacking' so well as leather which has undergone this treatment. With it, hemlock grain leather can be made to hold its color almost equal to that of pure oak tannage." Sumac not only helps the color but adds weight.

Bleaching solution.—For bleaching "the sides are dipped alternately in a bath of sugar of lead and then into one of sulphuric acid until the coloring matter is removed." "This bleaching process produces an immediate effect that is almost magical, but when the finished leather is exposed to the air and light for any considerable time the delicate pink and cream color turns to a 'murky brown.'"

Sumac bath.—"Sumac liquor forms a vegetable acid which, in its action on hemlock slaughter leather, not only neutralizes the color but softens the grain."

2. *Stains.*

Action of air and light.—"Leather dried in the open air will certainly dry dark, even if tanned with pure oak, and if with hemlock or mixed bark, will darken to a damaging extent. If a bright light, particularly if the sun's rays reach the grain or flesh, the leather turns brown and is permanently discolored."

Bark-liquor stains are sometimes found upon the grain side, due to liquor being pressed out of the flesh, which holds an undue proportion in draining after coming from the last layer; this will result if little cavities are allowed to form in packs when piled up for drainage, or when the flesh of one side comes in contact with the grain of another. The sides should be laid grain to grain and flesh to flesh. Here again we see the necessity of careful assortment before arriving at this stage. The sides should not be exposed to air and light, but should be covered with canvas, or they will finally become darkened so as to produce great discoloration. (This does not affect the leather except in appearance.) When dry on the surfaces the air may impinge upon it, but not a strong light, for its free admission will be sure to darken it.

If sulphuric acid is allowed to settle on the grain the stains produced will remain to the end; care should be taken to avoid this.

3. *Chemical defects.*

Black rot.—If strong warm or hot liquors are run from the leaches, either by "mistake or ignorance," in upon "half-tanned or green packs, 'black rot' is almost sure to result, particularly in the summer season."

The damage is caused by the decay of the animal fiber—actual decomposition of the untanned or raw hide. The external appearance of this damage appears as a sinking in of the two surfaces, caused by a general disturbance of the central tissues.

"When decomposition proceeds still further and the surfaces break, partially tanned 'puss' ("pus") exudes. This damage has been properly denominated the 'black rot' because upon the grain side, in addition to the 'falling away' appearance spoken of, the surface turns black, showing dark or black spots wherever the damage occurs, and this is generally in the thickest and best portion of the hide."

White spots.—These cause great depreciation in sole leather These defects are attributable to imperfect beam work.

The hides are soaked, milled, and sweated within a week, and depilated, while little attention is paid to cleaning the grain side, thus leaving grease, which resists the action of tan liquor. This should be removed in the beam-house. Any strong alkali, as potash or soda, applied to these spots will remove grease and enable the grain to take coloring and tannin.

"These spots may be avoided by thorough working on the beam nda by using a strong alkali on the spots affected, which may be discovered in the handlers when the sides have been colored slightly."

4. *Physical defects.*

"Old grain" and "hard spots."—These appear when the hides are so tender that the tanner does not work them on the beam until absolutely soft in all the thin parts, for fear of breaking them.

Knife marks or scores.—These are made on the flesh side by the butcher in skinning the animal. They are generally not deep enough to affect the grain. They make thin spots or lines, and when cut through they are known as "gashes" or "scores." Their position and size determine the damage done to the leather.

Hook marks.—These are produced by the hooking up of the sides from the vats. They are scratches made upon the grain side. It is a question whether sides should be laid flesh or grain upwards. If flesh up, there is danger in scratching the grain in "hooking up." If flesh down, some tanners claim that the color is affected (especially in hemlock tannages). The coloring matter in the tan-liquor is liable to settle on the grain ,giving it "a deeper, darker red." The general custom is to place the grain side up.

Horn marks.—These are caused by the goring of other cattle when a herd is inclosed in cattle-yards or are huddled together at the entrances of gangways in shipping to markets by rail; they are also made on the cars.

Prick marks or scratches.—These are produced by brutal drovers punching the cattle, when down in the cars, with sharp, long-handled pricks or goads.

Corral scratches.—These are scratches on the grain, received by the cattle when imprisoned in the large inclosures or corrals of Texas, California, and the Western plains, for the purpose of branding, counting, &c.

Brands.—These are generally frightful marks on the hip and shoulder, made by the owners of roving herds to designate their property. They very often cover a square foot of surface, and in the very best part of the hide. They destroy the value of half the side. Their presence should immediately reduce the hide to the second or third class, even before tanning. The only arguments that can be offered in defense of these large brands are, that they are conspicuous enough to be seen and recognized by the herder at quite a distance, and that in case the cattle are stolen it becomes difficult for subsequent brands to eradicate the traces of the first. Branding is generally confined to localities where the range or territory is occupied by a kind of tenancy in common.

Grubs.—By this term are known the larvæ of the *Hypoderma bovis* (DeGeer), or bot-fly of the ox. This fly is a dipterous insect of the family *Œstridæ*, (Leach). These larvæ are found during the month of May and in the summer in the tumors on the backs of cattle, and when fully grown, which is generally in July, work their way out and fall to the ground. They exist in the puparium from 26 to 30 days, and the fly appears from June to September. This species is found all over the civilized portions of the world.* The holes left in the hide of the animal by the extrusion of these larval parasites are from one to two-tenths of an inch in diameter, and are always found near or along the back line. Curriers generally fill up these holes when finishing the leather, but an expert readily detects their presence. These holes are a very serious defect in a side, and especially so as they occur in the best portion of it. They are fatal to harness-leather and belting.

SECTIONS OF DIFFERENT SOLE-LEATHER TANNAGES.†

Oak-tanned.—Section, glistening, marble appearence. Color, light brownish; of grain, light as if bleached a little.

Hemlock-tanned.—Section, glistening, mottled. Color, reddish-brown; of grain, dark-reddish tinge.

Union-tanned—

1. 50% *oak* + 50% *hemlock.*—Time of tanning, 5½ months. Section similar to that of hemlock leather—apparently but little difference. Leather firm; color of grain, lighter than hemlock.

2. 30% *oak* + 70% *hemlock.*—Time of tanning, 5½ months. Section, dark red. Color, darker than first specimen. This tannage produced 58 pounds of leather to 100 pounds of green hide.

3. 15% *oak* + 85% *hemlock* (extract).—Time of tanning, 4¾ months. Section and color darker than above. Leather, 57.58 pounds to 100 pounds green-salted hide.

4. 70% *oak* + 30% *hemlock.*—Time of tanning, 7 months. Section, about the same as No. 3. Color of grain, lighter than No. 3. This tannage produced 66 pounds of leather to 100 pounds of green-salted hide.

Extract of hemlock.—Time of tannage, 3 months. Section, dark red, not mottled. Exterior color, very dark.

In the same lot was found hemlock belting, very dark in color, having a woolly section, and also hemlock sole leather, tanned in 70 days, which was *apparently* good.

DRYING.

Avoid the use of extreme heat in drying leather after stuffing. Great heat brings the heat to the surface and gives to the leather a harsh feel-

*Vide Packard's "Guide to the Study of Insects."

†These sections were taken from a lot of samples of leather on exhibition at the same time.

ing. Exposure to light (especially to the direct rays of the sun) and to currents of air in drying should be avoided; a dark color will be the result of inattention to this precaution.

OILS.

Fish-oils should not be used in stuffing. They make the leather gummy and destroy the fiber. Many common oils are often used on account of their cheapness. An inferior kind of resin oil is sometimes used in finishing collar-leather. Exposure to heat causes the resinous matter to exude.

The writer has found such leather not only disagreeable to handle, but often entirely rotten and worthless.

HARNESS-LEATHER.

This leather should be carefully tanned and finished. It should be uniform in section, smooth to the touch, well blacked on the grain, and with the flesh smoothly shaved. The grain should not break when the side is closely folded flesh to flesh.

There should be no extrusion of grease upon the surface when exposed to the heat of the sun. A gummy feeling will indicate the inferior quality of the stuffing used in currying. There should be an entire absence of scratches, hook-marks, scores, grub-holes, "black rot," and "white spots." The back line should be nearly straight.

Only the best hides and those most uniform in thickness should be tanned for harness-leather. This leather should *not* be split.

These remarks apply equally to bridle-leather, except that the latter is made from thinner hides and is split.

GRAIN LEATHER.

Grain leather split from fully tanned sides is practically worthless. This operation is sometimes resorted to by tanners who have a stock of such leather on hand for which there is no sale. Sides intended for grain leather should be split on coming out of the first layer. Modern manufacturers can imitate goat, calf, or almost any other skin.

In ordering grain leather just mention the kind of grain desired, whether coarse or fine, as the external appearance of any skin can be duplicated indefinitely without extra cost. Very thick grain leather is more apt to break or crack than thin. Grain leather should be free from brands, scratches, horn and hook marks on the grain.

The middle line of the section of this leather should be lighter than the sides. The grain should not break when the flesh sides are tightly folded together in the hand, and should not have a harsh dry feeling when the fingers are passed along the folds, nor should it be gummy to the touch.

RUSSIA LEATHER.

"Russia leather" is tanned with willow bark, which gives it a light lemon color. The color and odor are after-productions. The peculiar aroma known as the "Russia-leather smell" is given to the leather by the use of "birch tar" in currying and finishing. This aroma is entirely independent of the tanning process, and may be omitted without detriment to the leather. The *best* genuine "Russia leather" is tanned by the Russians and finished by the Austrians. To Mr. Jackson S. Schultz,

our commissioner to the Vienna Exposition in 1873, and to the Hon. Marshall Jewell, our minister at St. Petersburg, belong conjointly the honor of having introduced the Russian birch tar into this country.

American manufacturers now make "Russia leather" as good as the best imported article, and costing much less. It may be well to observe that while we make leather as good and even better than the imported "Russia," we also make a very much poorer quality which imitates the genuine article so closely as to be readily sold as such. Besides, calf-skins, split cowhides, sheepskins, and even japanned paper are made up and sold as imitation Russia leather. The domestic article will probably supersede the imported before long, as the importation of these goods has declined nearly four-fifths within the last two years.

HEMLOCK VERSUS OAK.

Since the introduction in this country of hemlock bark as a tanning material, there has been a contest with regard to the relative merits of hemlock and oak tannages.* In this contest oak-tanned leather has always held a strong defensive position, being supported in its acknowledged excellence by old-time usage and stubborn prejudice. The English and American Governments have always required oak leather for their military supplies. Ask the official representatives of either of these governments why they cling to one tannage alone, and the answer will probably be, "We have *always* required oak leather for the 'service.'" The *why* is left unanswered. It is true, oak leather having stood the test of many generations may not be surpassed in its good qualities by any other tannage; but the question is, "Can it be equaled?" Some experts contend that it can and others that it cannot. But neither class can point to an exhaustive series of experiments and trials which prove beyond doubt the superiority of the chemical composition and the physical properties of the one over the other.

The most insuperable objection to hemlock leather appears to be the color. If the color should be found, by a long and carefully-conducted trial and comparison of the three principal tannages of this country, to be the only insurmountable difficulty with the hemlock, then let our educators evolve a new æsthetics in regard to the color of leather. There are objections to hemlock leather aside from its color. It contains a gummy extractive matter which hardens with age. This renders sewing difficult upon sole and harness leathers that have been kept in store for an indefinite time. Sometimes hemlock sole becomes as brittle as glass. In doubling up harness-leather (that has been long stored) between the hands the grain will often crack and break. The hemlock leather used in making shoes often discolors socks. It is not so smooth to the touch as either union or oak tanned leathers. It is estimated that from two-thirds to eight-tenths of all the leather tanned in the United States is hemlock leather. Its cheapness will always maintain its importance. It is possible that experiment might prove its non-adaptability for harness and bridle leather or that the tensile strength was affected of those and other leathers. But, at the same time, these experiments would indicate not only the qualities of this tannage, but would also point out the uses to which it could advantageously be applied in manufacturing supplies for the government service.

Were it found that hemlock leather could be largely utilized in supplying the wants of the government incidentally, and those of the people and trade generally, a vigorous and mighty stride would be taken in the

* By these it is to be understood that good tannages in both cases are meant.

right direction to suppress the wholesale and often wanton destruction of our oak forests. In regard to the supply of the United States service in time of peace, there is no doubt but that there is plenty of oak-tanned leather to meet all demands. The amount required is too small to excite a moment's attention. But in case of a war of any magnitude, when it might be a question of supplying the wants of 1,000,000 men or more, the case is very different indeed. The supply of oak leather would not be at all adequate to the demand.

In such an emergency, if the government still adhered to its custom of receiving nothing but oak-tanned leather (which it would be impossible to get,) a portion of the tanning interest would soon find a way to supply the increased demand by "doctoring" hemlock to resemble oak. The more conscientious would, perhaps, present a mixture of oak and hemlock, thrown in as union tanned.

Imitation oak leather can be made to defy detection by even an expert. Such is much of the oak leather, even now, in time of peace, foisted upon the credulous ignorance of our officials and inspectors.

It is not the intention of the writer to become an advocate of any particular tannage; while recognizing the great excellence of pure oak leather, he believes that good hemlock and union tannages will not only stand the test of experiment, but will be capable of being greatly improved in quality.

A careful determination of the relative merits of the different tannages. arrived at by intelligent and scientific investigation, would be of great value and benefit not only to the government but to the country, since the leather interest is, in importance, second only to that of agriculture.

Such an experimental investigation would necessarily be too long and expensive for any private firm to carry to a successful conclusion. It is only under the auspices of the government that it could be satisfactorily conducted. This work should be done by a commission of government officers, civil engineers, and intelligent practical tanners. One person, at least, of the number should be an able chemist.

These researches should not be confined to the analysis and testing of tanned leather alone, but should be extended to embrace the tanning itself.

This would require the commission to have access to some large tannery where experiments in tanning with different materials could be conducted. By doing this every circumstance attending the production of samples intended for future experiment could be noted with fidelity, accuracy, and intelligence. Many of the variable elements which might produce discord in the results, and cast a shadow of uncertainty over them, could thus be eliminated. The experimental tanning would be directly under the superintendence of a member of the commission, who would be an expert, and be actuated by a desire for truthful information and unbiased knowledge, so that no element of partiality would enter into the investigation.

ARMY SHOES.

The soldiers with whom the writer has served seemed to prefer sewed shoes to pegged ones; for, in marching the pegged shoes appeared to be stiff and unyielding, soon tiring the feet. In the hot sandy deserts of Nevada and Arizona the wooden pegs would drop out after getting very dry, and the sole would become separated from the in-sole and upper.

Another defect was noted in the same lots of shoes referred to, and that was the custom of filling in the soles with paste-board and scraps of leather.

As soon as the soldiers would wear out the thin sole of good leather

(a thing which would often occur in a very few days when marching over mesas and mountains covered with sharp cutting-stones), these cuttings, scraps, &c., would drop out, leaving nothing but the in-soles between his feet and the earth. One week's marching often leaves him barefooted upon the cactus plains and deserts.

Estabrook & Wire's clinching screws have been used in U. S. Army shoes; these screws were introduced in this country in 1868. This screw is made of brass wire. The brass is made and tempered expressly for this purpose. The machine for making this screw takes wire from two coils and cuts 160 screws per minute.

The screws are hand-driven. The point is so formed that in driving it allows the screw to upset or shorten "and take up the *settle* of the stock." The point forms a strong "hook clinch," which is imbedded in the in-sole.

Hemlock soles are often whitened with mineral acids.

MISCELLANEA.

"A perfect leather is recognized by its section, which should have a glistening, marbled appearance, without *any* white streaks in the middle." A section of well tanned leather will present (if oak) a uniform brown appearance. If badly or imperfectly tanned the interior portions will, more or less, resemble rawhide. When poorly tanned leather is cut, the section has not the glistening appearance of first-class leather, but is dull, buffy looking, with white or whitish mottling or streaks. When leather is too thoroughly tanned, *i. e.*, over-tanned, there is no grain left to buff, nor life or elasticity to the fiber.

"Leather may be too *hard* as well as too *soft*, but cannot be too solid. Keeping in view the distinction between 'hard' and 'solid,' the reader will understand that solid leather is a well-packed fiber, which cuts 'cheesy' and smooth, and not dry and husky, as much of the vitriol-raised leather cuts, increasing in the undesirable qualities with age." A *dark brown* stratum immediately underneath the grain indicates the use of sulphuric acid to "raise" or "plump" the skin. This cannot be removed by the tanner. "Sweat" leather treated with acid will break or crack by close folding.

The plumpest leather is made from green hides, as a large per cent. of gelatine is lost by curing and the subsequent operations of soaking, sweating, milling, &c.

Leather tanned rapidly with a saturated solution of nearly pure tannin will be harsh and hard, and will be poorer in quality than that tanned more slowly in weaker solutions of bark, which contain a greater or less amount of vegetable extractive matter that unites with the leather in varying proportions in slow tannages.

Dilute solutions only should be used in tanning.

The time employed in tanning is generally too short.

Mineral acids for bleaching purposes are objectionable.

All alkalies or alkaline earths darken or tend to darken the color of the future leather.

"Union crop" tanners sometimes use sour milk for bleaching purposes.

"Doped" hides are green hides which have been immersed in a pit or tank filled with salt and water. Hides thus treated gain two or three pounds each.

One hundred pounds of green-salted cowhides give from 40 to 50 pounds dressed leather, or from 50 to 60 pounds of sole leather.

Hides for patent or enameled leather are tanned whole.

Steer hides are usually used for enameled leather. They should be of large spread and well taken off.

Hides from the tropics do not make as good leather as those of temperate latitudes.

Bull-hides are inferior to either steer or cow hides, making a thick, spongy leather.

Imitation buckskin, collar, and sole leather are made from bison hides.

The skin of the white whale, tanned, makes a fine, tough upper leather.

Lamb, deer, antelope, and peccary skins are tanned for glove leather.

Alligator and rattlesnake skins have been tanned for making boots and shoes.

Walrus skins, when tanned, make a coarse, spongy leather, from half an inch to an inch in thickness, used for buffing-rolls and for covering polishing-wheels.

Boots have been made of human skin. A pair made from human skin, tanned with sumac, had uppers of a russet color.

Splits from enameled leather are wax-finished and sent to England.

Splits in the rough are sold for the in-soles of shoes.

"Flesh" finished splits make cheap shoes, but they wear well.

In some tanneries the scraps from the currying-shop are made into in-sole leather or into backs for horse-brushes.

The National Leather Company, of Detroit, by Charles Richter's patent process, can get calf-skins from the hair on to the counter in 20 days.

Colored leathers are made by the use of analine colors.

"A perfect oak stain can be made with oxalic acid and French yellow; add as much water as will take up the acid, but put half a pound of French yellow to a gallon of water, adding a of couple ounces of sugar of lead to make it strike in quicker. The leather should be thoroughly soaked before using the stain on it, and if the 'English color' for sole-leather is wanted, omit the French yellow and use instead a little pipe-clay.

Tannerine is a chemical preparation designed to replace urine in preparing leather for coloring. It is said to give permanency and brilliancy to the most delicate colors, and to be free from the offensive odor of urine.

The Wilcox tannery, in Elk County, Pennsylvania, is the largest tannery in this country, and the largest exclusively sole-leather tannery in the world. Its production for several years past has been about 200,000 sides of hemlock sole-leather per annum. Next to this comes the Eagle Valley tannery, at Ridgway, Pa., tanning 150,000 sides.

Leather board is manufactured in the United States as a substitute for leather.

Leatherette is a substance resembling morocco leather so closely that few persons are able to distinguish the difference. It is manufactured in England, and is composed of fibrous felt, grained and finished to imitate pebble, strait grain, patent leather, or any other. It is colored to resemble morocco, and is used for book-binding, belts, boxes, pocket-books, and hat-linings. The cost is 50 per cent. less than any other material.

Artificial leather is made from leather cuttings, India rubber, and aqua ammonia. The cuttings are cleansed, put into a machine and worked into a fibrous mass, then mixed with ammonia, after which the gelatinous material is pressed into molds or rolled into sheets and dried. The material is now hard, non-elastic, and soluble in water.

The India rubber is washed, dried, dissolved in oil of turpentine or

some similar solvent mixed with ammonia, and then thoroughly incorporated with the leather mass. When the mixture becomes homogeneous it is either pressed into molds or rolled into lengths and dried; while drying it is subjected to progressive pressure. That intended for the soles of boots and shoes receives the greatest amount of pressure. It is then dyed or glazed to imitate natural leather. The firmness and durability of this material are of a doubtful character.

Vegetable leather is being introduced as a substitute for leather. It consists of cotton or cotton waste and dust, cocoanut fiber and other textile products, carded into sheets of wadding and treated to saturation with a decoction of a certain species of marine moss that is abundant along the coast of New England. The sheets are placed upon heated zinc plates, saturated as above stated, dried, subjected to heavy pressure under rollers, coated with linseed-oil, and dried again. They are then coated with vegetable wax, run through hot fluted rollers, and finished by passing between polished rollers.

It is bronzed, silvered, and varnished, and is said to be a good substitute for leather in fabricating harness, military equipments, carriage, table, and chair covers. It may be used in book-binding.

APPENDIX.

Tanning materials.

Oak bark.—The tannin or tannic acid, used to prepare leather from the skins of animals, is found in the bark of the various species of *Quercus*. The bark obtained from the oak tree has long been most extensively used for tanning. The bark should be stripped from the tree in the spring, as it then contains a much larger quantity of tannin than that taken from the tree at any other time of the year. The oak bark used for tanning purposes on the Pacific coast is obtained from the chestnut oak; the principal supply coming from Santa Clara and Mendocino Counties, that from Gilroy, in the former county, being more highly prized. The best bark is stripped from thrifty trees, about two feet in diameter. After stripping, the bark is stacked under cover to dry, for if rained upon a portion of the tannin will be washed out and lost. When dry, it is ready for sale. The dry bark is ground in a bark-mill, in order that the tannic acid may be more easily extracted when the bark is put in the vats.

India gambier.—This substance is extracted from the leaves of a species of acacia, a shrub or bushy tree, grown from slips or cuttings on plantations in the island of Singapore and on the mainland opposite. When these bushes are two or three years old the leaves are stripped off and boiled to extract the gambier; this is reduced to the consistency of sirup, and the leaves are raked out and the water is evaporated by placing it in pans and exposing it to the heat of the sun. These pans of gambier, when dry enough to handle, are cut into cubes, sacked and sent to Singapore, where the cubes are pressed into bales varying from 240 to 266 pounds, covered with mats, and are then ready for shipment. Gambier thus prepared is a tough, inspissated mass, with a gritty, gray fracture, and a very astringent taste. The shrub exhausts the soil where grown in about five or six years.

Sumach is a plant belonging to the genus *Rhus*.

Sicily sumach.—The variety known in the market as Sicily sumach is imported from Italy, Sicily and the other Italian islands, and is extensively used for the production of bright leathers both by tanners and curriers. It is imported in a pulverulent state, in sacks of 120 pounds each, and possesses a much lighter color than Virginia sumach. It is

used on the Pacific coast chiefly for tanning "skirting," a light-colored leather used for making saddle-skirts and saddles, and gives great uniformity of color and a much softer toning to the leather than oak bark.

American sumach is indigenous to a belt of country extending from Maryland through Virginia and the Carolinas, thence through the northern sections of Georgia, Alabama, Mississippi, and in parts of Kentucky and Tennessee; also found in large quantities in New York and Pennsylvania, but the northern climate appears too cold to develop the tanning properties of this plant.

Virginia sumach.—Virginia takes the lead in producing sumach, where great care is taken in selecting and grinding it. The gathering season begins about July 1st and ends with the first frost, which turns the leaf red, rendering it worthless. The strength is in the leaf and leaf-stem. It is sold in sacks of 120 pounds. each, is of a gray color and pulverized, and is much used in tanning calfskins. It makes a softer leather than any other tanning material, and is much used in the production of bright leathers.

Valonia.—This is the product of the great prickly-cupped oak. This tree grows in Turkey, the Morea, the Levant, Italy, and the Italian islands. The acorns with the cups attached are imported in sacks of 200 pounds each, which are ground in the bark-mill. They are of a yellowish color. The cups contain an abundance of tannin.

Prices of tanning materials.

	Coin.	
Oak bark, chestnut oak, from Santa Clara County, California	$17.25	per cord.
Oak bark, chestnut oak, from Mendocino County, California	15.25	per cord.
Sumach, Sicily	$115.00 @ 125.00	per ton.
Sumach, Virginia	45.00 @ 90.00	per ton.
Gambier, India	.07½	per lb.
Valonia	.08½	per lb.
Oil, neat's-foot	.95	per gal.
Oil, polar (sperm oil)	.65	per gal.
Oil, tanner's (common whale-oil)	.52½	per gal.

OILS.

Below are given the most important oils used in tanning and currying, together with their prices. Of course these prices vary with the fluctuations of the market, but they will serve as a relative standard of value:

Nomenclature.	Price per gallon.
Oil, winter sperm, bleached	$1 75
Oil, winter sperm, natural color	1 65
Oil, neat's-foot, pressed, extra	$1 15 @ 1 20
Oil, neat's-foot, crude, pure	1 05
Oil, neat's-foot, second quality	85
Oil. winter black-fish, bleached	95
Oil, winter black-fish, natural color	80
Oil, sea-elephant, refined	75
Oil, sod, English	70
Oil, sod, American	60
Oil, Newfoundland cod	65 @ 68
Oil, straits	55 @ 65
Oil, bank	45 @ 55
Oil, fish, pressed, bleached	48
Oil, fish, pressed, natural color	42
Oil, Delaware	40

Colors of oils.

Kinds of oil.	Color.	Remarks.
Oil, neat's-foot, pressed	Light straw	Very clear.
Oil, neat's-foot, No. 1	A shade more yellow than above	Very clear.
Oil, resin, stuffing	Yellow; darker than above	Very clear.
Oil, resin, finishing	Still darker	
Oil, winter black-fish, bleached	Colorless	Clear.
Oil, fish, refined	Reddish-yellow	
Oil, sea-elephant, winter, bleached	Straw	
Oil, sperm, natural color	Dark straw	
Oil, whale, natural color	Dark	
Oil, whale, natural, virgin	Black	
Oil, paraffine	Dark	
Oil, seal, refined	Colorless	
Oil, cod	Almost black	
Oil, straits	Almost black	
Oil, cod, refined		Clear.

Prices of leather, how packed, and ordinary uses.

Kinds of leather.	No. of sides per roll.	Average selling price in coin.	Ordinary uses.
1. Sole	10	24 cents per pound	Soles for boots and shoes and making trunks.
2. Harness	10	32 cents per pound	Making harness.
3. Bridle	12	$4.50 per side	Bridles, light harness, and covering saddles.
4. Collar	20	17 cents per square foot	Collars.
5. Buff	12	18 cents per square foot	Men's gaiters, boots, and all cheap shoe-factory work.
6. Grain	12	do	Fishermen's boots and carriage-tops.
7. Wax	12	16 @ 20 cents per square foot	Brogans and all coarse work.
8. Polish	12	15 cents per square foot	Ladies' gaiters and shoes.
9. Oil pebble	12	17 cents per square foot	Men's coarse boots, &c.
10. Trunk	12	do	Covering trunks and valises.
11. Splits	25 @ 30	30 cents per pound	Brogans and cheap shoes.
12. Skirting	12	35 cents per pound	Saddle-skirts and saddles.
13. Latigo	15	17 cents per square foot	Latigos and aparejos.
14. Lace	12	25 cents per side	Lacing belts, smiths' aprons, for sewing collars, aparejos, &c.
15. Bellows	12	16 cents per square foot	Making bellows.
16. Belting		Varies	Belts for machinery (sold per running feet).
17. Calfskins	12	80 cents @ $1.05 per pound	Making fine boots and shoes.
18. Green hides.	(Light)	7 cents per pound	For tanning.
	(Heavy)	9 cents per pound	Do.

GLOSSARY.

Abating.—See Bating.

Bate-stone.—A scouring stone curved to fit the beam or inclined rest of the beam-house, and used to scrape the skins after taking them from the manure-vats. (Fig. 23.)

Bating.—Is steeping the hides in a lixivium of hen-manure after coming out of the lime-vats. This process tends to separate the lime, oil, and glutinous matter, and to make the skins pliant, porous, and ready to imbibe the tanning principle.

Bark-mill.—A mill used for grinding and pulverizing oak bark, valonia, &c. (Fig. 21.)

Beam.—This consists of a heavy block of wood, upon which the currier stands; into one end is mortised or hinged a stiff piece of wood, faced with a piece of light wood, to which is glued a plate of mahogany or lignum-vitæ. The face of the plate must be a perfect plane to agree with the edge of the currier's knife in shaving. The inclination of the beam depends on the convenience of the operator, who holds the leather by pressing it against the beam with his legs and body. (Fig. 18.)

Blacking (for harness and bridle leather).—A decoction of iron-rust and vinegar, or iron-rust and sour wine or sour beer, applied to the grain side of the leather after it has been stained. The vinegar solution is the best. After this application the leather is said to be blacked on the grain.

Blacking (for wax leather).—A compound of lampblack and soft soap, laid on flesh side with a brush. The skin is now said to be blacked on the flesh, or waxed.

Bloom.—A yellowish deposit upon the grain side of a hide or skin derived from the bark used in tanning. Its ease of removal depends upon the hardness of the water used by the tanner. The softer the water the more readily can the bloom be removed.

Bruising.—Doubling grain side of a hide together, and rubbing it on the flesh with a graining-board.

Boarding.—Doubling the leather with the flesh sides together, and driving the fold forward and drawing it backward by the graining-board. It makes the leather supple and raises the grain.

Buffing.—Taking off thin shavings from the grain side with a buffing-slicker until the skin is very thin; the object being to make cowhide imitate calfskin. The operation is finished by whitening.

Clamp.—A wooden bench-screw, carrying two checks, used to prevent the leather from moving during the operation of stoning or slicking. (Fig. 11.)

Clearing-stone.—A fine pebble, used to remove from the currier's knife the scratches made by the rub-stone. The Scotch gray and Welsh clearing-stones are generally octagonal in form, four inches thick and from six to eight inches long.

Cork arm-board.—A graining-board, made of the outer or dead bark of the cork-oak. It has no grooves. (Fig. 5.)

Currier's knife.—This is a double-edged rectangular knife, about twelve inches in length and five inches in width, with a straight handle at one end and a cross-handle at the other, the axes of both being in the plane of the blade. This knife is the most important tool used by the currier. The blade is a plate of steel carefully and peculiarly tempered, and is ground to a straight edge by rubbing it forward and backward upon the rub-stone. The scratches left by the latter are removed by rubbing on a fine Scotch or Welsh clearing-stone, which leaves a wire edge. The edges are then wiped dry and oiled. The workman now takes a turning steel, and by rubbing it carefully from end to end the edge is gradually turned completely over. To keep it in this condition requires the greatest skill, as it cannot be used more than a minute without losing its keenness. To restore this, the point of a small steel (finger-steel) is first run along the groove formed by turning the edge over, and then the steel is made to pass along outside the edge. When used, the plane of the knife-blade is held almost perpendicularly to the skin. (Fig. 1.)

Dampened—Damped.—To moisten the leather with a wet sponge, in order to make it dry evenly. When hides are dry, they must always be dampened previous to skiving or shaving.

Dubbing or Daubing.—*See* Stuffing.

Finger-steel.—A carefully-prepared instrument used for restoring the edge of the currier's knife while in use. (Fig. 7.)

Flattening.—Same as shaving, except in some cases the skin after skiving is shaved *across* (*i. e.*, nearly at right angles to the skiving), and then flattened by being shaved again in the same direction as the skiving.

Flesher—Fleshing-knife.—A long two-handled and somewhat blunt-edged knife, curved to fit the sloping rest of the beam-house. Its cross-section is concave downward. It is used to scrape off the hair, scarf-skin, loose flesh, and cellular tissue. (Figs. 3 and 20.)

Fleshing.—This operation is performed in the beam-house. The hair is scraped off the hide, the loose and adherent flesh removed, together with lime and dirt, by a two-handled knife, called the flesher, curved to fit the convex surface of the inclined beam.

Flesh side.—The side of a skin or hide next the animal's flesh.

Glassing.—Smoothing and polishing a side of leather by means of a plate-glass slicker, or a glassing-jack.

Glassing-jack.—A machine driven by steam-power, to which is fitted a plate-glass slicker, for smoothing and polishing leather. (*See* Jack.)

Graining—Consists in giving to the leather a granular appearance upon the grain side, by either the graining-board or the pebbling-machine.

Graining-board.—A rectanular piece of wood, with the upper surface a plane; the lower one is convex, and fluted with parallel grooves, which run perpendicular to its length. A leather strap attaches it to the hand or arm. The grooves are coarse or fine, as occasion requires.

Grain side.—The side of a hide or skin from which the hair has been removed.

Handlers.—Same as stringers.

Handling.—Taking the sides out of the vats into the air, smoothing them out and piling them together on one side to drain, after which they are returned to the stringers. Each time they are handled they are put back into a stronger ooze.

Jack.—The jack is a machine to which may be fitted a steel, glass, or lignum-vitæ slicker, a Walpole scouring-stone, or a pebbling-roller, according as the leather is required to be slicked, smoothed, polished, stoned, or pebbled. It performs these operations more quickly and effectively than they can be done by hand, and with less expense.

Junk vat.—This is a large vat, into which is pumped the tan-liquor or ooze which has been deprived of a great part of its strength in the layers. This liquor is again utilized by being pumped into the stringers, where weak ooze is required.

Layers—Lay-aways.—These are vats or pits in which the sides are laid away or stratified with ground oak bark after coming out of the stringers. The sides are laid flesh down, to prevent the hook scratching the grain in taking out. The layers contain the strongest infusion of oak bark.

Liming.—The process of immersing the fresh hides in vats containing milk of lime.

Mill.—Is a large wooden drum or cylinder, about eight feet in diameter, and four feet in height, water-tight, and having large wooden pins projecting radially from the interior concave surface toward its horizontal shaft. Near one end of the drum, and exterior to it, is a small iron pinion, whose shaft is parallel to the shaft of the cylinder, which engages the cogs upon the circumference of the drum, causing it to revolve from eight to twenty times per minute. The pinion-shaft is put in motion by a belt connected with shafting. The mill is used for stuffing light leather and for various other purposes. After stoning, skiving, and shaving, the sides are quite hard, and are put in the mill with some tan liquor to soften them and to make them porous. In stuffing, a charge of about twenty sides, more or less, is put in the mill, with the proper amount

of dubbing, and it is then set in motion for fifteen or twenty minutes, when the milling is completed. (Fig. 26.)

Moon knife.—A circular knife, ten or twelve inches in diameter, having a round four or five inch hole in the center to introduce the hands in working it. It is concave, presenting the form of a conical zone. The concave part is applied to the skin. The edge is turned over a little to prevent it from entering too far into the leather. It is used for shaving off the coarser, fleshy parts of the skin. (Fig. 4.)

Ooze.—This is an infusion of oak-bark or other tanning material with which the vats are filled for tanning leather. The strength of the ooze is usually determined by the astringency of the taste of the liquor. The barkometer (Fig. 9), a kind of hydrometer, is sometimes used. But little reliance can be placed upon its indications, as the ooze contains other soluble ingredients besides tannin, which affect its specific gravity.

Pebbling—Is done by passing the side of leather through a pebbling-machine, which, by means of a metallic roller having its cylindrical surface covered with indented reticulations, stamps a grain upon it.

Pebbling-machine.—Attach a pebbling-roller to the jack, and it constitutes this machine.

Polar-oil.—The best quality of sperm-oil.

Polishing-jack.—A machine armed with a lignum-vitæ slicker; used for polishing leather when considerable pressure is required.

Rolling-mill.—A small brass roller, driven by steam-power and passing over a concave bed covered with brass, to which any degree of proximity may be given by a system of compound levers, thus giving any desired pressure. It is used for rolling sole leather.

Rosin-oil.—Common oil. A compound of melted rosin and linseed-oil.

Rub-stone.—A block of sandstone placed on a strong trestle of a convenient height, upon which the currier rubs and sharpens his knives and other tools. The upper surface should be a perfect plane. Those made of Nova Scotia sandstone are cylindrical, about eight inches in diameter and one foot in length.

Scouring on the flesh.—On being taken out of the water the skins are spread out and set on the scouring-table by passing a steel slicker over the flesh side, which brings the grain in close contact with the table, and, being wet, it adheres to it. A bountiful supply of water is applied and rubbed briskly over the flesh side with a stiff brush, whereby the pulpy portions of the surface are scrubbed off, and the skin presents a soft whitened appearance and the pores are opened.

Scouring on the grain.—The skin is set on a scouring-table by a slicker, which stretches it and at the same time loosens the bloom. The grain side is kept uppermost, and is smartly brushed with a stiff hair brush, using at the same time plenty of water, when the slicker is again used to remove the water and loosened bloom. A stock-stone is often used instead of the slicker to loosen the bloom.

Scouring-table.—This is a large firmly built table, with a mahogany bird's-eye maple top (sometimes the top is of slate or marble); it is about twelve feet long and four feet wide, so constructed that the water used in scouring may pass off readily upon the side opposite to that on which the workman is engaged.

Set—Set out.—To set a side of leather, it is spread upon the table or stone when wet, and is smoothed out on it by the vigorous use of the slicker, and, owing to its wet condition, the air is easily excluded from under the leather, and it sticks to the table. A thin layer of oil will serve the same purpose.

Shaving.—In this operation the currier's knife is often driven from the top to the bottom of the beam, thus taking off shaving after shaving, removing all the inequalities left after skiving, and making the leather of uniform thickness, also leaving a beautiful smooth face on the flesh side. This operation is often called flattening. The shaving or flattening is done almost at right angles to the skiving.

Short-hair knife.—A keen-edged knife used in the beam-house to remove short hairs (new growth) from the hides. (Fig. 8.)

Sizing.—A paste made of flour, soap, beeswax, a little linseed-oil and water. It is applied to the grain side with a sponge. It fills the pores and serves to give a smooth finish to the leather.

Skiving.—The skin is laid over the beam and the rough fleshy portion is shaved off by the currier driving his knife obliquely a few inches at a time, and keeping the right-hand handle of the knife slightly in advance of the left-hand one in the downward motion.

Slicker, steel.—A rectangular piece of steel about five inches long. The edge is also a rectangle, and is sharpened upon the rub-stone by grinding it perpendicularly, and then upon each side, producing thus two edges (or rather right angles) by which the leather is scraped instead of being cut. It is used to remove excess of water, oil, etc., from leather. Its applications are various. It has a handle like that of a stock-stone. (Fig. 12.)

Slicker, glass or lignum-vitæ.—These are similar in form and dimensions to the steel slicker, but the blades are made either of thick plate-glass or lignum-vitæ. The edges are rounded instead of being rectangular. They are chiefly used to smooth out and polish-leather. (Fig. 14.)

Slicker, buffing.—This has a narrower, longer, and very much thinner blade than the others. Its edge has an acute angular longitudinal groove running along it, thus forming two very keen cutting edges, which are kept in proper condition by the finger-steel. It is used by placing one edge and the stock flat upon the leather, the latter being stretched upon the table, and forcibly pushing it forward, taking off thin shavings from the grain surface. When one edge is dulled the slicker is turned over and the other side used until it loses its edge, when the finger-steel must again be brought into requisition. (Fig. 25.)

Slicker, whitening.—This instrument has almost the same form and dimensions as the buffing-slicker (which see), but instead of a re-entrant angle along the edge, it has a very narrow rectangular one, whose angles are kept sharp by the finger-steel. (Fig. 25.) *See* Whitening.

Slicking.—For this the slicker is used. The latter scrapes the leather, removing superfluous water or grease, and eradicating the marks left by the stock-stone.

Soft-boarding.—Boarding or bruising the leather on the flesh side; it renders the skin very pliant. *See* Bruising.

Splitting.—This operation consists in reducing the sides of leather to a uniform thickness by passing them through the splitting-machine. The latter can be adjusted to split the sides to any required thickness. It is mainly employed in the preparation of thin and light leathers.

Staining.—Applying with a hair brush to the grain side of leather a solution of logwood, sal soda and soft water. It gives a dark color to the leather.

Stock-stone.—A flat rectangular scouring-stone, five or six inches long and half an inch thick, fixed in a stock or handle. It is used for scouring, stretching, and removing inequalities in the leather. (Fig. 13.)

Stoning—Is forcibly driving the stock-stone over the leather to remove

inequalities, stretch it and render the grain smooth. The North River and Walpole scouring-stones, or stock-stones, are generally used.

Stoning-jack.—The jack with the stock-stone attached is called a stoning-jack. It is used for stoning and scraping leather.

Stringers—Are large vats in which the skins brought from the beam-house are first placed, and so tied up as to hang lengthwise in the vats and parallel to each other. The vats are filled with a weak infusion of oak-bark.

Stuffing.—A mixture of tallow and neat's-foot oil, or tallow and sperm oil, with which the dampened leather is coated. Great care is requisite to give the proper amount of stuffing, as too much is injurious. In drying the water evaporates, while the greater part of the oleaginous matter is absorbed, making the leather supple, easily manipulated, and impervious to water.

Stuffing-brush.—A stiff hair brush used in stuffing leather. (Fig. 24.)

Table-brush.—A soft hair brush used to sweep shavings from the buffing table. (Fig. 19.)

Turning-steel.—A round steel instrument used to turn the edge of the currier's knife. (Fig. 6.)

Vat.—A large, rectangular pit used in tanning.

Whitening.—This operation taxes the skill of the currier to the utmost. The leather is laid over the beam, and with an extremely fine-edged knife a thin shaving is taken from the flesh side. This may also be performed by the whitening slicker. In the latter case the leather is laid on a table, the slicker laid flat upon it, and driven with great force repeatedly down the length of the side, taking off parallel and very thin shavings. The edges of these instruments must be so true that not a scratch shall appear upon the surface of the leather.

Worker.—A two-handled, blunt-edged knife, curved to suit the inclined rest of the beam-house, and is used to scrape the hides. (Fig. 2.)

NOTE.—For Figures 1 to 25 see Plate I, and for Fig. 26 see Plate II.

Explanation of plates.

PLATE I.

Tanners' and curriers' tools.

PLATE II.

Stuffing mill, &c.

PLATE III.

Fig. 1. Usual outline and trim of hide, given by Mr. Jackson S. Schultz.

A A, Bellies.

B B, Bends.

C and D, Shoulders.

Sometimes the shoulders are cut so as to include the neck, and in that case both "C" and "D" are cut in one piece; but it is more common to cut "C" as the shoulder. All outside of the bends marked "B B" is termed "offal," but with the specific names given.

Fig. 2. English nomenclature of hide.

PLATE IV.

Apparatus for leaching bark.

Fig. 1. Allen & Warren's center-post sprinkler.

Fig. 2. Allen & Warren's hanging sprinkler.
Fig. 3. The dumping leach.

PLATE V.

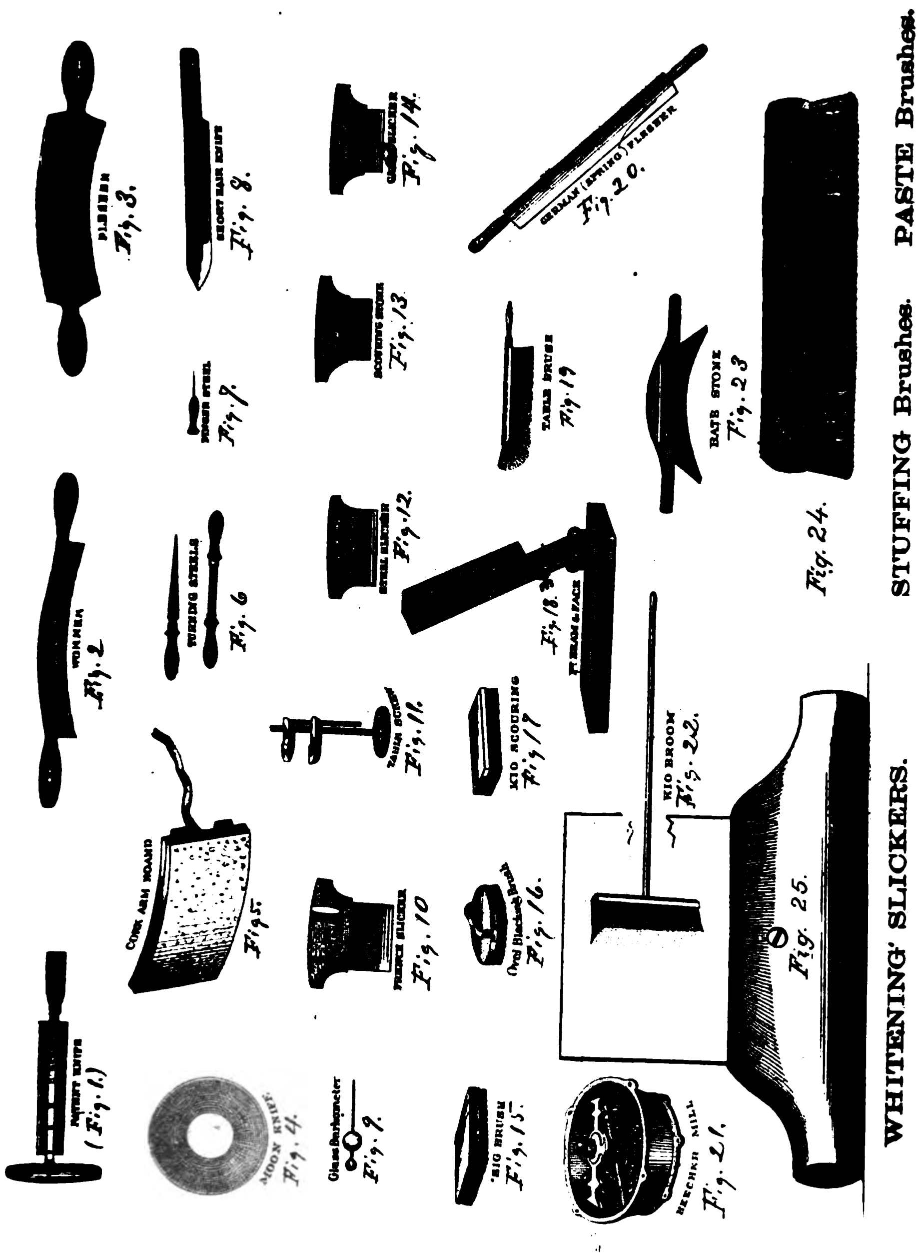
Fig. 1. Sole-leather-rolling machine.
Fig. 2. Sole-leather-rolling machine, Bright's patent.
Fig. 3. Union leather-splitting machine, Richardson's.
Fig. 4. Keystone bark-mill.

PLATE VI.

Fig. 1. Union leather whitening and buffing machine.
Fig. 2. Tapley heel-burnishing machine.
Fig. 3. Impression-stitch machine. Uses no thread or needles.
Fig. 4. Crimping-machine for boots and shoes.
Fig. 5. Welt and stitching machine.

PLATE I.

TANNERS' AND CURRIERS' TOOLS.



Accompanying Appendix K, 1878

PLATE II.

ELEVATION OF "THE MILL".

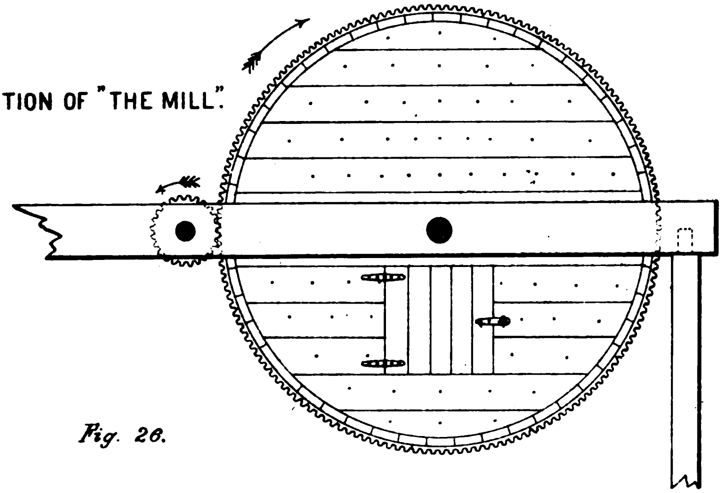
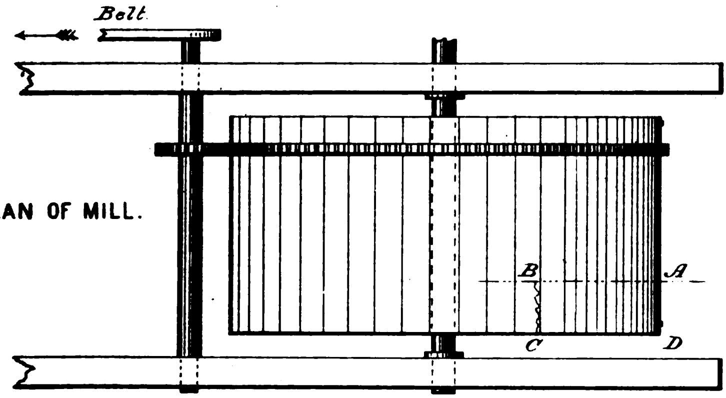
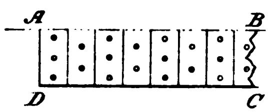


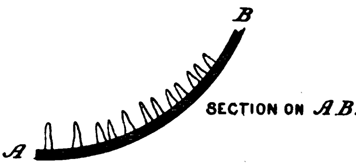
Fig. 26.

PLAN OF MILL.





DEVELOPMENT OF *AB*.



ARC OF CYLINDER.

PLATE III.

Fig. 1.

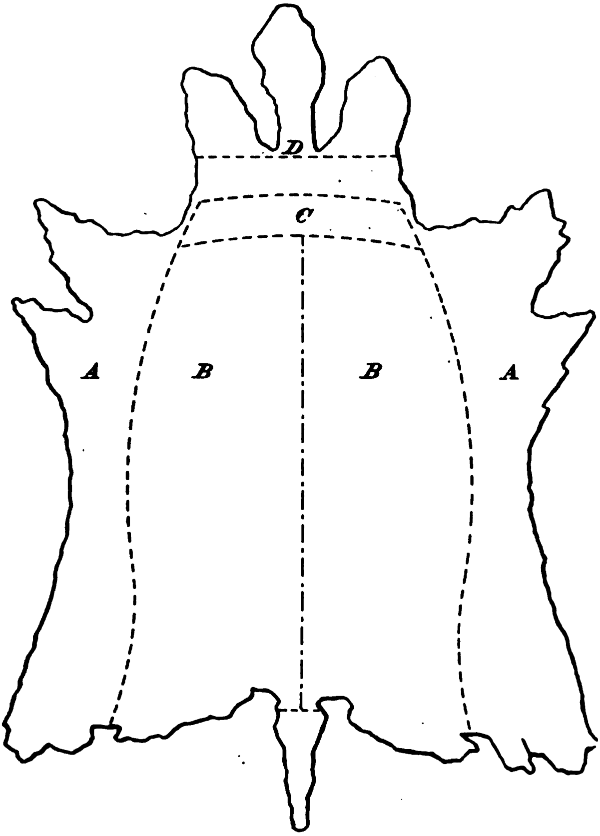
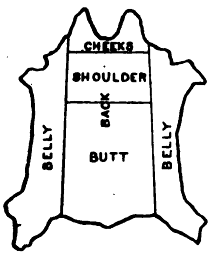


Fig. 2.



Accompanying Appendix K, 1878

PLATE IV.

Fig. 1.

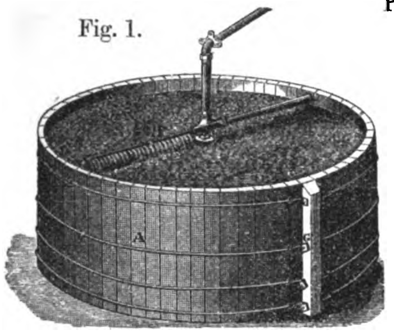


Fig. 2.

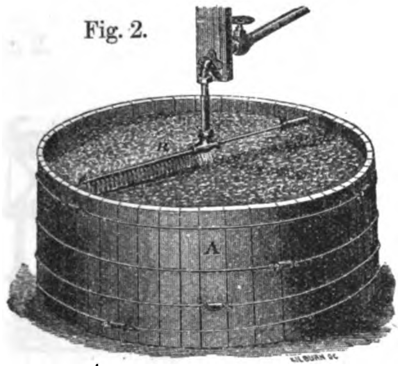
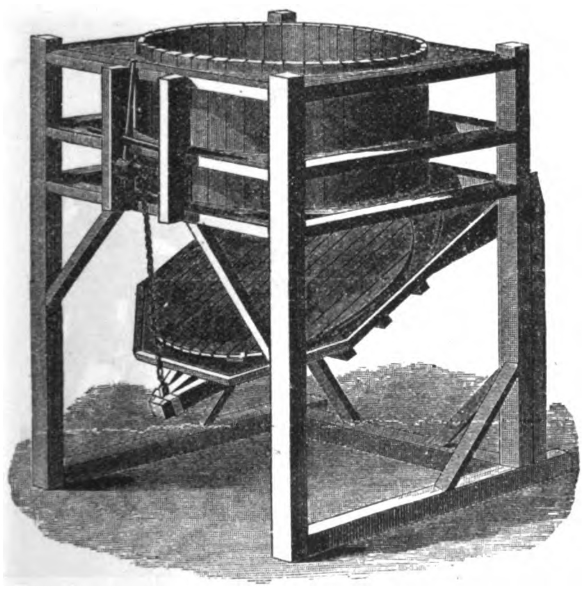


Fig. 3.



Accompanying Appendix K, 1878

PLATE V.

Fig. 1.

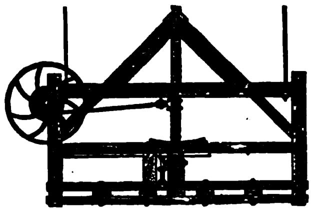


Fig. 2.

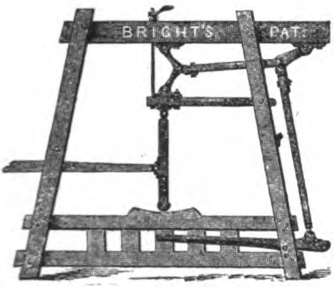


Fig. 4.

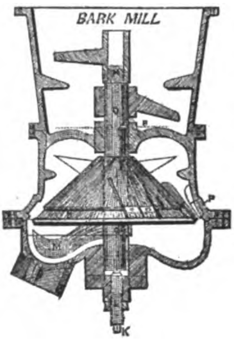
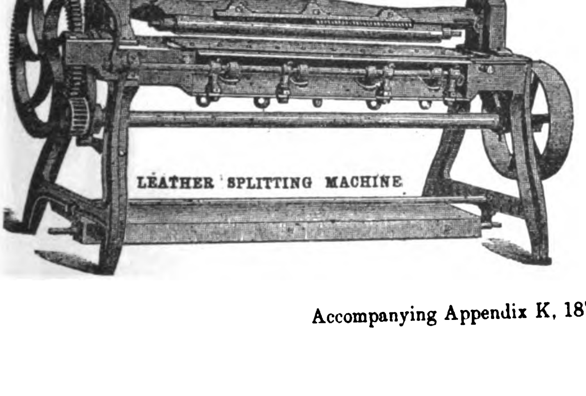


Fig. 3.



Accompanying Appendix K, 1878

PLATE VI.

Fig. 1.

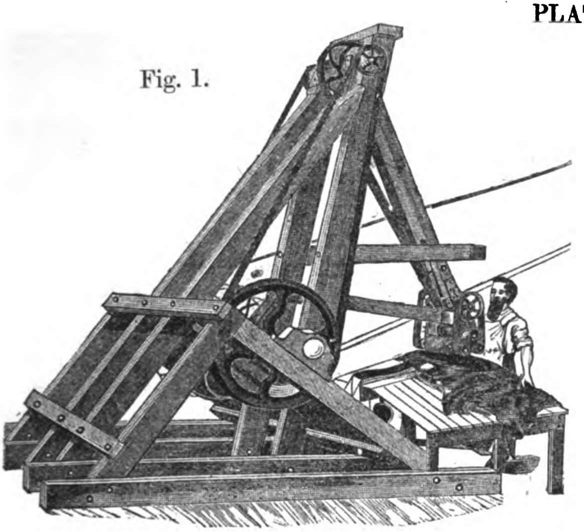


Fig. 2.

Fig. 3.

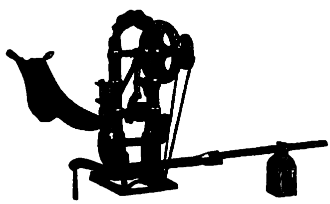
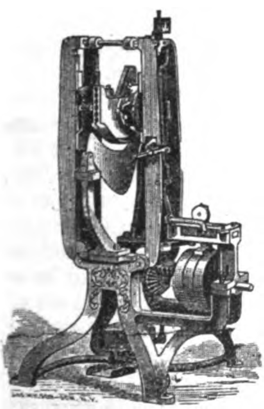


Fig. 5.

Fig. 4.



Accompanying Appendix K, 1878

APPENDIX L.

RIFLED CANNON EMPLOYED IN THE SIEGE SERVICE IN FRANCE, ENGLAND, PRUSSIA, AND AUSTRIA, FOR THE EXECUTION OF VERTICAL FIRE. TRANSLATED FROM THE "REVUE D'ARTILLERIE," BY FIRST LIEUT. CHARLES S. SMITH, ORDNANCE DEPARTMENT, UNITED STATES ARMY.

(Four plates.)

1. FRANCE.—RIFLED HOWITZER OF 22 C. M., CAST IRON, HOOPED.

This cannon, adopted in 1864, has been obtained by rifling and hooping an old smooth-bore howitzer of the coast service. The smooth-bore howitzer gave a fire mediocre enough, and the bursting of shell in the bore was not uncommon, without any very apparent reason therefor. It is probable that, notwithstanding the employment of a sabot, the shell turned in the bore and the fuse was forced into the cavity. The rifling has permitted of the employment with this piece of a projectile weighing more than triple the spherical shell, and that with an accuracy of fire which was very remarkable at the epoch when the trials were made. Since 1864, therefore, the howitzer of 22 c. m., rifled and hooped, should be considered as having replaced the mortar of 32 c. m., the fire of which was too uncertain to utilize the effect of its bomb of 95 kilos. weight, and of which the reactions were so violent for large charges of powder, that a satisfactory platform for the piece was never obtained.

The rifling of the numerous smooth-bore howitzers on hand in the maritime directions of the land artillery having recently been decided upon, the study of this piece presents an interest of reality. The details of the plan are to be found in the "*Revue d'Artillerie*" (January, 1873), and in the "*Aide-Memoire of Naval Artillery*," and will not be reproduced here; we will only give some information relative to the hooping, to the interior dispositions, to the projectiles, and to the carriage.

Hooping.—In order to apply the hoops, the first reinforce of the mortar is turned down cylindrically, in such manner that after the hoops are put in place the piece preserves very nearly its original diameter (the weight is augmented 100 kilos., carrying it up to 3,700 kilos.). The hoops are put on hot, and are of puddled steel, very tough and elastic—soft steel, having a homogeneous and regular grain, being selected. The shrinkage (difference between the exterior diameter of the cannon and the interior diameter of the hoops, measured when cold) is 1 m. m. in round numbers; this is at least what was adopted at first. In 1860, the shrinkage was reduced in most of the pieces, under the belief that it occasioned cracks in the metal; later the more energetic shrinkage was resumed; finally it appears that the ideas of 1860 were returned to, so that it is possible that a more feeble shrinkage will be adopted for rifled howitzers in future. The unhooping of cannon out of service has shown that the shrinkage has diminished a little in service, and that the same hoops may be re-employed.

The six hoops of the howitzer of 22 c. m. stop just in rear of the trunnions. There is no trunnion-hoop.

The vent.—The vent of the howitzer of 22 c. m., hooped, has the same site as in the smooth-bore howitzer, but in order to avoid degradation of the hoops in its vicinity, it is pierced for a No. 1 vent, the description of which we borrow from the work of Gadaud, lieutenant in the navy, en-

titled "Artillery of the French Marine in 1872." (See also *Aide-Memoire of Naval Artillery.*)

The vent bush (Plate VII[a], Fig. 1) is composed of two parts—of a tube of cast steel, and of a tube of hardened copper. The copper tube incloses a steel ring; its upper part is cylindrical and abuts against the steel tube. The latter is threaded for a certain length, and screwed into the body of the gun. The copper piece is placed in a recess, widened at the top to prevent it (the copper) from falling out; the steel tube, on the other hand, prevents it from rising up; finally, the steel ring is supported against the steel tube, and thus opposes any considerable upsetting of the copper piece under the action of the gas.

This system was adopted as a consequence of numerous trials, and has given good results.*

The diameter of the vent is 6.5 m. m. at the outer aperture, and contracts to 5.6 m. m.

Interior disposition.—The rifling consists of three basket-handled grooves, similar to those of the cannon of 30, with a parabolic development, and having an equal inclination of 6° to the generatrices of the bore at the muzzle. These grooves present a particularity that does not exist in the cannon of 30; they are prolonged in rear by a part contracted and of little depth, in order to receive the isolating flanges of the projectile (prolongations of the grooves).

The bore is enlarged a little at the muzzle in order to facilitate the insertion of the projectile. The cartridge-chamber is a truncated cone; it is shorter than the old chamber, and the length of the bore is thus increased by 10 c. m.

Projectiles.—The ordinary projectile is a shell of a total weight of 79.8 kilos., and of the usual pattern of the marine shells; its length is about 2¼ calibers, and contains a bursting charge of 4 kilos., which fills the chamber. The projectile is fitted with a percussion mechanism of double reaction, the description of which we borrow from the work of M. Gadaud. A hammer of bronze (Plate VII[a], Fig. 2) incloses in its interior some rifle powder, and is maintained in place by two trunnions. A cap is fitted to the upper part of the fuse and held in place by a copper disk. Two iron pins prevent the hammer, on leaving its lodgment, from coming in communication with the charge of powder. The projectile being thrown with a sufficient velocity, the hammer breaks its trunnions and strikes against the pins; when the shell is arrested the hammer continues to move forward, in virtue of its inertia, and strikes in the cap. It is necessary that the projectile should fall from repose through a height of 15 meters in order that the apparatus should act successfully. This system acts with more regularity than the Tardy apparatus, with which a part of our shells have been equipped.

The howitzer of 22 c. m. throws two kinds of canister, consisting of sheet-iron cases filled with zinc balls; the weight of one is 31.100 kilos., and contains 56 balls of 44.3 m. m., disposed in four tiers; the weight of the other is 39 kilos., and contains 12 large balls of 89 m. m. (weight 2.5 kilos.), in three tiers, with a tompion of wood in the center.

Exceptionally a massive cylindrical projectile is thrown of 82 kilos., which, fired with a charge of 6 kilos., may be employed with some chance of success against plates of 12 c. m. at ranges below 100 meters.

Apparatus for pointing.—Two circles of steel, secured by two dowels, are heated and put on to the body of the piece, one in front of the vent

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* It was found, in the experiments of 1871, that the gas penetrated between the copper and steel at their junction, and that the former was forced into the canal of the vent, thereby choking it. (Extract from work quoted above.)—C. S. S.

and the other in front of the trunnions; the first carries the seat for the hausse; the second, the front sight. The line of sight has a length of 1.20 m., and lies 0.23 m. to the left of the plane of fire.

The hausse consists of a steel rod, which is engaged in the hausse-seat; a horizontal gauge slides along this rod and is held in position by means of a set-screw; it carries a movable sight-notch, which serves to correct the drift and the deviations due to the wind and the velocity of the vessel (in case of firing at sea).

There are three hausses: hausses Nos. 1 and 2 are designed for direct fire (charge 5 kilos.); No. 1 serves up to 11 cables' length (2,200 meters); No. 2, up to 21 cables' length (4,200 meters); No. 3, for the fire of bombs. The hausses Nos. 1 and 2 are graduated in cables' lengths; hausse No. 2, in millimeters.

The hausse No. 3 is only employed for 1,200 meters and upwards, because firing with charges inferior to 1 kilo. has been abandoned. Upon the lower part of this hausse is engraved a table indicating for each distance the charge, the height, and drift.

Carriage.—The rifled howitzer of 22 c. m. has been fired up to the present on the wooden marine carriage described in the *Revue d'Artillerie* (January, 1873, page 309), and represented on Plate VII[a], Figs. 3 and 4. The attempt was recently made at Gâvre to fire it upon a coast carriage, model of 1866, with a charge of 6 kilos., and under an angle of 40°, but the trunnions of the two howitzers experimented with were broken—one at the third, the other at the eighth shot. The same effect was produced at the sixth shot upon a carriage and chassis for a cannon of 19 c. m. It was sought to augment the elasticity of the carriage, and the howitzer was fired on a coast carriage, the cast-iron cheeks of which were surmounted with wooden supports for the trunnions; under an angle of 40°, and with a charge of 6 kilos., the recoil was 1.60 m., and the depression of the chassis from 7 to 8 m. m. At the first shot the right cheek was cracked; at the second shot firing became impracticable. The plan was then tried of attaching trunnion plates to the carriage with wooden cheeks; at the second shot the right trunnion was broken, as well as the roller on the left side of the carriage. This demonstrated very clearly that the trunnions of the howitzer are too feeble to admit of firing from carriages of but little elasticity. These trials should be resumed upon a wooden carriage, mounted on a coast chassis of cast iron. If it is only desired to employ the howitzer for bomb firing, the marine carriage, which has always behaved well, and which requires only five men for maneuvering, would suffice; for the direct fire it would not have a height suitable to the *genouillère* (height of axis of trunnions, 1.155 m. only); the recoil, also, would be too considerable, because of the very light weight (750 kilos.) of this carriage; it is questionable, therefore, whether it is very useful to employ the howitzer in direct fire. Perhaps it would withstand the fire upon a wooden carriage provided with cheek brackets of iron, as in the Prussian carriage, for the support of the trunnions.

Fire.—The charges are contained in cartridges constructed upon a mandril of 159 m. m. Between the cartridge and projectile is placed a wad of seaweed 155 m. m. in length; charges inferior to 3 kilos. are attached to the wad to prevent them from turning.

The direct fire is executed with a fixed charge of 5 kilos., which gives an initial velocity of 245 meters for the ballasted shell of 79.8 kilos. (powder of Ripault).

The following table, extracted from the *Aide-Memoire of Naval Artillery*, gives some information on the fire of the rifled howitzer of 22 c. m. The numbers that figure there relate to the ballasted shell of 82 kilos., whereas the service shell, since 1864, weighs 79.8 kilos.

Fire of the rifled howitzers of 22 c. m., employed as a mortar.

ANGLE OF FIRE, 40°.

Charge. (Powder of Ripault.)	Initial velocity.	Range.	Derivation.	Duration of trajectory.	Mean deviation.		Angle of fall.
					Longitudinal.	Lateral.	
Kilos.	*Meters.*	*Meters.*	*Meters.*	*Seconds.*	*Meters.*	*Meters.*	° ′
1.00	115	1,314	55	15.1	35.5	2.9	41 28
1.25	129	1,614	63	16.9	39.6	3.6	41 31
1.50	142	1,902	71	18.4	43.2	4.3	41 57
1.75	152	2,178	79	19.7	46.5	5.0	42 16
2.00	162	2,440	86	20.8	49.6	5.7	42 34
2.25	171	2,696	92	22.0	52.4	6.3	42 52
2.50	180	2,937	98	23.0	55.1	7.0	43 10
3.00	196	3,391	110	24.9	59.9	8.3	43 44
3.50	210	3,805	121	26.5	64.2	9.5	44 16
4.00	223	4,188	131	27.9	68.2	10.7	44 40
5.00	242	4,775	147	30.0	74.2	12.7	45 32
6.00	257	5,219	159	32.1	78.8	14.3	46 6

2. ENGLAND.—8-INCH RIFLED HOWITZER.

Figs. 5, 6, and 7 (Pl. VII[a]) indicate the principal dimensions of the 8-inch rifled howitzers of the English artillery. The grooves have a uniform pitch of 1 turn in 16 calibers; their profile is of the system known as the Woolwich. The length of the rifled portion of the bore is 4.4 calibers. The mode of construction of the howitzer is analogous to that of a gun of the same caliber. The piece is composed of a central tube of steel and of exterior coils of wrought iron. The weight of the piece is 2,320 kilos., with a breech preponderance of 100 kilos.

The projectile is a common shell of 79.7 kilos. with interior capacity for a charge of 5.9 kilos.; its length is 615 m. m.—say three calibers. This great length of shell merits attention, as we recall to mind on this point that the essays made by the Prussians in firing shells of this length were unsuccessful. The English are more fortunate, probably because of the short twist of their rifling, which is only 1 turn in 16 calibers. It seems, however, notwithstanding the statement in their report, that they are not able to give to their shell a stability upon its trajectory comparable to that of the Prussian or Austrian shell; we may be assured of this when we consider the very extended limits between which the ratios of the mean deviations to the ranges vary.

Fire of the English 8-inch rifled howitzer.

Charge. (Powder R. L. G.)	Angles.	Duration of the trajectories.	Ranges.	Mean deviations.		Derivations.
				Longitudinal.	Lateral.	
Kilograms.	° ′	*Seconds.*	*Meters.*	*Meters.*	*Meters.*	*Meters.*
0.454	40 41	9.3	449	5.5	1.9	2.0
0.907	40 19	13.6	944	2.8	2.2	33.2
1.814	10 24	5.6	775	......	......	8.2
	20 13	10.7	1,339	14.0	4.0	33.3
	40 9	19.3	1,935	24.0	4.5	81.8
2.722	20 8	13.3	2,150	45.0	4.1	42.0
	30 6	18.9	2,753	30.6	3.2	91.9
	35 6	22.0	3,035	36.6	5.3	120.0
	40 6	24.7	3,172	41.5	4.8	151.8
3.629	20 6	14.8	2,694	60.9	1.5	51.7
	30 5	21.7	3,591	25.3	2.5	122.5
	35 5	24.8	3,824	34.7	1.2	151.5
	40 5	......	3,958	32.9	3.0	183.5
	20 5	16.0	3,027	90.0	5.0	59.0
	30 7	23.5	4,074	24.0	3.5	150.0
	40 5	30.1	4,478	31.0	8.9	242.0

This table sums up some results of the firing; it is proper to remark that the means which they contain are generally taken from a series of three shots, which is far from sufficient to enable us to judge of the accuracy of a piece. These figures, compared with those which will be given further on, show that the English howitzer does not attain either the precision in range of the Prussian mortar or the accuracy in direction of the Austrian mortar.

The English employed, for the experiments with the 8-inch howitzer, a carriage of wrought iron, weighing 1,360 kilos. Under great angles the recoil rarely exceeded two meters; under an angle of 20° and a charge of 4.536 kilos., it attained 4 meters, and it was very violent under small angles. This carriage has not been adopted; it is too light for a piece of this caliber, not weighing itself over 2,300 kilos.

To recapitulate, the English are successful in firing from a very short piece a shell 3 calibers in length, which enables them to employ a very large interior charge; but, so far as we are able to judge from the mean figures taken from a very small number of shots, they have not been able to attain in an equal degree the regularity of fire of the Austrian and Prussian mortars; their howitzer, however, is not the less remarkable. The results of their experiments prove the possibility of firing feeble charges in pieces of large caliber, with projectiles more elongated than are ordinarily employed with those pieces, on the condition of shortening sufficiently the twist of the rifling; it is a question whether it ought not to be reduced to 1 turn in 14 calibers for a howitzer of 9 inches.

Before adopting their system of rifled howitzers the English had made some fruitless essays in tubing and rifling smooth-bore cast-iron mortars of 10 and 13 inches, which they thus reduced to 8 and 9 inches caliber.*

3. Prussian rifled mortar of 21 c. m.

The piece.†—Captain Manceron has described in the *Revue d'Artillerie* (tome 1, page 382), two models of rifled mortars employed during the war of 1870–1871. The present mortar (model 1871), represented in Fig. 8, Pl. VII*, has the same general form that those had, but it differs in weight and dimensions. (See *Revue d'Artillerie*, February, 1874, page 410.) We will confine ourselves here to the following information: Caliber of piece, 209.3 m. m.; weight, 2,800 kilos. without the fermeture, (the old mortar weighed 3,500 kilos.); number of grooves 30, inclined at an angle of 7° (twist about one turn in 25 calibers). The length of the rifled portion is about 5½ calibers.

The mechanism of the fermeture is a Kreiner double-prismatic coin of 225 kilos. weight; the crank is removed to allow the piece to pass between the cheeks when firing under great angles.

The obturator is a copper ring, the rim of which rests against the inner surface of a steel ring screwed into the rear part of the powder-chamber. (See *Revue d'Artillerie*, tome 1, page 16.)

Projectile.—The ordinary projectile of the mortar of 21 c. m. is the oblong shell common to this piece and to the steel-hooped gun of 21 c. m. This projectile is of a total weight of 80 kilos., and contains an interior charge of 5 kilos. It is covered with a thin envelope of lead attached by the chemical process. It has at the bottom a tap-hole,

* The English have recently experimented at Eastbourne with rifled howitzers of 6.3-inch and 10-inch caliber, but the trials demonstrated that the pieces were very deficient in point of accuracy of fire.—C. S. S.

† Bronze mortar, model of 1870, transformed.

which is closed by an iron screw-plug. A washer of lead pressed in between the plug and the wall of the hole renders the fermeture hermetic. The square head of the plug projects from the bottom. Two cylindrical holes formed in the fore part of the shell permit of its being carried by means of shell hooks.

The length of the shell was fixed at 2½ calibers after a series of experiments had made known that a shell of 3 calibers turned over at a short distance from the piece, and that those of 2¾ calibers balloted upon their trajectories.

The interior chamber of the projectile is tarred to prevent explosion in the bore by the shock of the grains of powder against the walls. Finally, the shell is fitted with the well known percussion fuse of reaction, with a safety pin. The Prussians, as well as the Austrians, employ a fuse of slow action.

Carriage.—The wooden carriage with *cheek* brackets* has been described in the *Revue d'Artillerie* (tome 1, page 384)—a carriage analogous to the first Austrian model, which will be examined further on.

Fire.—The maximum firing charge of the mortar of 21 c. m. is 3.5 kilos., which gives an initial velocity of 215 meters for oblong shell. The powder employed is probably the ordinary cannon powder.

The following table gives some information on the elements of the fire:

Fire of the Prussian mortar of 21 *c. m.*

Charge.	Angle of fire.	Range.	Derivations.	Initial velocity.	Maximum rise.	Mean deviations.		Circumscribed rectangle of all the shots.
						Longitudinal.	Lateral.	
Kilos.	*Degrees.*	*Meters.*	*Meters.*	*Meters.*		*Meters.*	*Meters.*	*Meters.*
3.5	30	3,531	143.5	215	....	12	6	60 x 30
	45	3,991	293.4			15	9	75 x 45
	60	3,229	397.0					
3	30	3,004	116.0	197.3	429	5.2	5.5	31 x 32
	45	3,306	246.0		800	10.3	2.7	62 x 16
	60	2,812	296.0		1,275	11	6.5	66 x 39
1	30	863	30.0	100	....	6	0.6	30 x 3
	45	953	62.0					
	60	835	95.0					

Sketch 9, Plate VII[a], indicates the result of firing a series of 10 shots at a distance of 1,860 meters and under an angle of 30°. The circumscribed rectangle of these 10 shots is about 35 m. x 7; the grouping of the shots is very remarkable.

Effect of fire against shelters.—Some information upon the effects of fire of the Prussian mortar against shelters has already been published in the *Revue*, in the article of Captain Manceron (tome 1, page 397), and also in that of Captain Petit (tome 3), relative to the effects of the Prussian artillery before Paris. We extract from the latter the information relating to the rifled mortar.

The shell of 21 c. m. fired at a maximum distance of 2,000 meters had a maximum penetration of only one meter in recent earthen embankments of little consistency, but it produced some craters of from 3 to 4 cubic meters, and of such a nature that the parapets were, in certain points, destroyed for a height of 0.60 m.

*These brackets (Plate VII[b]) increase the height of the axis of the trunnion; they are bolted upon the top of the cheeks.—C. S. S.

At the fort of Montrouge, upon the arches of the traverses, covered over with at least 2 meters of earth, the shells of 21 centimeters, notwithstanding their feeble penetration, produced in the thick masonry of 60 centimeters some fissures and disjunctions, which necessitated the propping up of the arches.

At the fort of Vanves, two covered traverses, which presented a flank to the shots, had their arches damaged at the height of the haunches, notwithstanding their mattresses of earth of 250 meters; the ashlars were driven inward 4 centimeters over a surface of ½ m. q.

At the fort of Issy, a shell of 21 centimeters, falling almost perpendicularly upon a little magazine of munitions, traversed two meters of earth, the arch of 60 centimeters, and burst in falling upon the ground of the magazine.

At the fort of Vanves, a shell of 21 centimeters, falling upon the terreplein of the bastion, cracked the arch of the casemate under the terreplein; this arch had a thickness of 75 centimeters, and was covered over with 0.80 centimeter of earth, perfectly rammed by the continual passage of the men.

The arches of 1 meter in thickness, of certain great powder magazines, frequently resisted badly enough when they were covered over with 1 meter of earth, but resisted perfectly when the covering of earth was raised to 1.80 meters.

In the court of the Double Crown of the North some shelters were constructed with horizontal roofs composed of rails spaced at 1 meter, and having a maximum span of 1.70 meters; these rails, solidly supported, were covered with a flooring of joists and a mattress of earth. When the mattress had a thickness of 3 meters the shelters resisted well; the shelters which were covered with only 1.50 meters of earth were pierced on the first day of the bombardment.

At the fort of Vanves, a shelter covered with the trunks of trees of 30 centimeters, with a span of 4 meters, and a minimum thickness of 4 meters of earth, was not traversed, but the ceiling was sometimes disturbed.

A shelter formed of nine frames of 25 centimeters scantling, with spaces of 1 meter, covered with a coffer of joists, with 2 tiers of facines and 2 meters of earth, was stove in by a shell of 21 centimeters, after having been unsettled by many shells of 15 centimeters.

The shelters of timber-work in the fort of Issy, with from 2.50 meters to 3 meters of earth, were more or less compromised.

Some blind shelters of joined beams of from 30 to 35 centimeters, well sustained, covered with a row of fascines and with 1.20 meters of earth, withstood the fire of the shells of 21 centimeters.

In comparing the information which precedes with the results cited by Captain Manceron, it will be seen that the fire of the Prussian mortar, under an angle of 60 degrees, and at a distance of 2,000 meters, is formidable to hollow traverses, even when covered with 2.50 meters of earth, and to the arches of casemates under 80 centimeters of well-rammed earth; that the effect of isolated shots is not dangerous to powder-magazines with one meter of earth, but that nevertheless it is probable that the latter would not withstand many shots fortunately grouped. As to horizontal blindages, they are only able to resist when they have a certain elasticity, and have the resistance of a row of joined trunks of trees of from 30 to 35 centimeters, of a short span, and covered with fascines and at least 1.20 meters of earth. These indications give, then, the minimum resistance required in shelters to withstand the fire under the conditions above announced. In practice, it is necessary

to exceed considerably the minimum dimensions, for the figures, if accuracy of fire show that it is possible to group the shots upon a small surface, at ranges attaining to, at least, 4,000 meters. Projectiles arriving from these great distances, under great angles, would have a very considerable penetration.

4. AUSTRIAN RIFLED CAST-IRON HOWITZER OF 8 POUCES (21 C. M.).

This piece is chiefly remarkable in that it gives great accuracy of fire, notwithstanding its very limited length (the rifled portion of the bore being only 4 calibers). In the *Revue* (tome 1, page 395) will be found some information which we will complete by some facts borrowed from the Austrian collection, entitled "Mittheilungen über Gegenstände des Artillerie, und Genie-Wesens," dwelling chiefly upon the details of experiments which have a practical utility.

Fabrication.—The first rifled mortar of 8 pouces constructed in Austria was cast on a core, with the object of avoiding the spongy metal which is readily produced toward the center of large pieces cast solid; and, also, because it was hoped, from the fact that charcoal pig strongly decarburates by fusion, that a more homogeneous grain would be obtained by casting under a less thickness of metal. Again, in a piece cast solid, as the solidification takes place from the exterior, the interior layers are in a state of initial tension, whereas it is more advantageous, from the point of view of resistance to the firing, to place them under an initial compression. It was this consideration that induced Major Rodman to cast his large pieces upon a hollow core, cooled by a current of water. The Austrians employed, to produce the cooling of the core, a current of air generated by a blowing engine. This cooling is otherwise necessary, independently of all consideration upon the molecular constitution of the cast iron, in order to prevent the hollow core from becoming heated to redness and bending.

The mortar was cast with a heavy sinking-head (about 3,000 kilos.). The core was composed (see Figs. 10 and 11, Plate VII^b) of a tube fluted on the exterior surface, upon which was wound a fine iron wire, thus leaving a series of longitudinal canals for the escape of the gas and vapors from the exterior of the core; the iron wire was itself surrounded by a light rope, upon which was applied a layer of clay mixed with horse and cow dung. The lower part of the core was inserted into the mold, while the upper part was free to dilate in a cylinder supported by the casting basin above the mold. The jets of iron were directed into the molds by two tubes. The basin being very nearly filled with the liquid metal, and the current of air permitted to circulate through the core, the tubes were opened, and two jets descended vertically into the mold without touching either the core or the walls. The casting proceeded without incident; the current of air which came out of the core was inflamed on leaving it. The scoria which floated upon the surface of the cast iron remained liquid, and the eddies produced by the jets prevented them from becoming attached either to the core or to the mold.

The temperature of the current of air (0.300 m. cube per second) rose in half an hour after casting to 100° centigrade; and in an hour and a half it attained 124°, descending after 9 hours and a quarter to 100°. The current was then shut off and the interior examined, but as after 20 minutes the interior was slightly red, the current was turned on again. (The same observations were made after 12, 15, and 18 hours and a half.) Finally, after 24 hours, the current was shut off, and the tube ceased to

become red. The air, which circulated freely through the core, came out after 46 hours, at the temperature of 130°.

According to the calculations of Lieutenant-Colonel Holececk the air current had absorbed 0.229 of the total heat of the metal.

Seventy-two hours after casting the piece was removed from the mold; it was ascertained that the rope around the core was completely consumed, which was probably occasioned by the accidental penetration of the air through small fissures.

The casting of the piece left exposed perfectly clear surfaces. The proofs of resistance upon bars of the cast iron taken from different places gave results very uniform, and showed that the resistance of the metal obtained by the process of casting employed was as great as in some specimens taken from a little piece cast under good conditions.

The Piece.—The *Revue d'Artillerie* (tome 1, page 386 and following) gives for the plan of the piece some figures which it is useless to reproduce here. We will recall only that the diameter of the bore is 209 m. m.; the length of the rifled part is a little more than 4 calibers; the 30 cuneiform grooves have a twist of 1 turn in 60 calibers.

The fermeture is that of the Krupp system—a cylindro-prismatic coin; the coin is prolonged by a lunette for the passage of the charge.

The vent was originally pierced in the coin, in the direction of the axis of the bore; this position forced a return to the position of charging when the primer missed fire; this maneuver caused a loss of time, and exposed to some derangement the position of the projectile. More recently the vent has been pierced perpendicularly to the axis, and a copper bushing employed.

Obturator.—Different obturators have been tried in the mortar of 8 pouces. The first was a Broadwell ring, but it did not expand sufficiently; a residuum of powder became attached to its exterior surface, and it was necessary to clean it at each shot, as without this precaution it moved out of its recess, prevented the coin from being replaced, and scratched some furrows on the bearing surface of the latter. The ring was then made thinner, but the obturation remained incomplete. After a series of trials, an obturator of tombac* (white copper) was adopted, with a bottom of pasteboard. (*Bodenkappe aus Pappendeckel.*) Figure 12, Plate VII[b], represents an obturator employed in Prussia, with the Wahrendorff fermeture, and which ought to bear a close analogy to the one employed with this mortar.

The edge of the obturator in tombac is turned up, and operates in firing in the same manner as that with a pasteboard bottom employed in Prussia with the Wahrendorff fermeture. The pasteboard bottom is set in the ring of tombac.

To procure a good obturator, it is requisite that the rim of the ring be coated with tallow. The best obturators of this system have been able to undergo the firing of from fifty to one hundred shots. On an average, for inferior charges of 3 kilos., a thin ring is necessary every seventy shots, and a bottom every ten shots; for large charges, a strong ring every forty shots, and a bottom every five shots.

Ammunition.—In the experiments ordinary cannon powder (powder A) was employed, both for the firing charge and for the interior charge of the projectile.

*In order to employ this obturator in the first mortar experiments, the recess of the Broadwell ring was bored cylindrically, and a steel ring set in place by pressure; but the latter did not work well; it was displaced to the rear, even when it had been fastened by four screws, obstructed the maneuvering of the coin, and finished by arresting the experiments.

The cartridges are centered in the chamber by means of two splints; those of a weight inferior to 0.728 kilo. are placed in a wooden sabot, which is composed of half a hollow cylinder, closed at the rear by a half-disk of board one pouce thick; upon this disk is fastened a small circular board which fits into the copper gas-check. This sabot assures the inflammation of the small charges and reduces the space given to the expansion of the gas.

The projectile (Figure 13, Plate VII^b) is a cylindro-ogival shell of 2½ calibers in length; this length was adopted as a consequence of comparative firings with shells of 2 calibers and 2½ calibers in length. In the bottom is a tap hole closed by a screw plug of iron; the thin coating of lead is attached by the chemical process; the weight of the shell is 87 kilos. It should be remarked that this shell is longer and heavier at the point than the Prussian shell of the same caliber.

The shells were furnished for the first essays with a percussion fuse of reaction analogous to the well-known Prussian fuse. The safety-pin left its place during the passage of the shell through the bore, and was pinched between the projectile and the walls of the bore, and left some imprints upon the latter; it was therefore necessary to secure these pins more firmly by means of wedges.

Later, an effort was made to obtain fuses which should not burst the projectile until it had completed its penetration. After some fruitless attempts, some fuses were finally obtained which gave an interval of from 0.1 sec. to 0.23 sec. between the shock of the shell and its explosion.

Carriage.—The first experimental mortar was mounted upon a wooden carriage (described in the *Revue*, February, 1873, page 387), which by means of three strong screws could be raised sufficiently to be placed upon wheels; it was connected then to a siege limber by means of a pole. This carriage was not very satisfactory; it required nearly an hour to mount it upon wheels or to dismount it upon the platform; it was not possible to move it upon the latter but at the price of great effort. Two men applied at the pointing apparatus were not able to raise the piece from an angle of 30° to that of 10°, the angle of loading; it was necessary to apply some men to a lever introduced into the bore at the muzzle, and to allow the breech to repose upon another lever placed across the cheeks. Finally, under an angle of 75° and a charge of 4.5 kilos., the cheeks were broken; iron supports for the trunnions were then placed on top of the cheeks.

Later, two carriages designed to be moved more conveniently upon the platform were tried. One of these was of plate-iron and the other of wood, both having the same form as the primitive carriage, and furnished with two trunnion-supports of iron; each was provided with eight rollers (four for the longitudinal movement and four for the lateral) mounted upon eccentric axes; the carriage was raised up by throwing the eccentrics into gear, the axes being maintained in position by means of keys; the movement of the carriage being terminated, the rollers were thrown out of gear and the carriage lowered upon the platform.

The original apparatus for pointing was retained for the new carriages, but in order to pass easily to the position of loading a toothed arc was attached to the piece, working in a pinion attached to the carriage. Finally, to transport these carriages, they were raised by means of screw-jacks, and an axle and wheels attached; afterward they were connected to a limber by means of a curved pole.

At the end of a small number of shots (118) the firing on the wooden carriage was stopped, because the rollers no longer operated; the front

transom was twisted into contact with the platform and the carriage dislocated.

The carriage of plate-iron sustained 677 shots without injury. The graphic representations of its movement during the firing showed a maximum sinking of 15 millimeters for the platform, followed by an ascension of 30 millimeters for the carriage.

The carriage of plate-iron has been adopted.*

Pointing.—The exterior surface of the mortar carries a seat for the quadrant and a lodgment for the derivation sight.

Originally the direction was given by means of a plumb-line running over a traverse of wood placed in rear of the carriage; but the line of sight being very short, this method of pointing was defective. It was perceived that in bringing the carriage against some reference marks placed upon the platform the shots were grouped more regularly; on account of which, it was decided to adopt an apparatus analogous to the *apparatus for indirect pointing*, which was applied to the Prussian siege carriages, and which is described in the *Revue d'Artillerie* (tome 3, page 2). (See Appendix.)

Fire.—Firing charges have been employed varying from 0.560 kilo. to 5.600 kilos. Care is always taken to assure the position of the projectile in its chamber by means of the ramrod, in order that it shall be sufficiently engaged in the rifled part not to fall back upon the charge in passing to the position of firing, which would prove a source of irregularity in firing.

It was observed in firing with small charges that the axis of the shell moved through the air nearly parallel to itself; the projectile fell upon its base, pivoted, and turned over with the point directed toward the piece. This effect was produced under an angle of 75°, even up to ranges of 1,500 meters. It was clearly seen, in following the projectile through the air, that the axis inclined progressively toward the right. In proportion as the charges were increased this movement of the axis was less sensible, the shell fell flat, afterward point foremost, pivoting less and less at its point of fall. (Analogous results were observed in France in the experiments of 1861.)

For the minimum charge, 0.728 kilo. has been adopted. With this charge, under an angle of 65°, the axis of the shell inclines first to the left, then passes to the right after the point of culmination, and the projectile arrives at a mean range of 380 meters, with its axis very nearly horizontal. Four shells fired under these conditions have burst at their point of fall.

Experience demonstrated that the largest charge that could be utilized with the particular powder employed was 5.040 kilos. Nevertheless, some shots were fired with a charge of 5.600 kilos., and an extreme range obtained of 4,512 meters, under an angle of 45°. Under this angle, five shells were driven 0.80 meter into the earth and remained there; ten others plowed a furrow of 2.50 meters on 0.32 meter.

The smallest angle of fire adopted was 20°; this angle being taken as the limit in order to avoid having deep embrasures, and because, under smaller angles, siege cannon give better results, and with less trouble.

For small charges high angles should be employed; otherwise, these charges give little precision of fire; in this case, the axis of the shell describes a conical surface of a great angle about the tangent to the trajectory, the projectile coming to the ground either flat or upon its base.

The penetrations in the gravel of the polygon of Steinfeld did not ex-

* See Plate VII[b] for model of carriage finally adopted.

ceed 85 centimeters (charge 5.040 kilos., angle 60°); the charged projectiles made craters of 2 meters in diameter, and from 50 to 90 centimeters deep (one-twelfth of the fragments remaining in the crater).

The following table gives the results obtained in firing with the principal charges; the numbers contained therein, relative to the accuracy of fire, will be examined further on.

Charges.	Angles.	Ranges.	Derivations.	Mean deviations.		Circumscribed rectangles for 95 per cent. of the shots (calculated).	Duration of trajectory.	Recoil.
				Longitudinal.	Lateral.			
Kilos.	*Degrees.*	*Meters.*	*Meters.*	*Meters.*	*Meters.*	*Meters.*	*Seconds.*	*Meters.*
	50	358	31. 1 D.	20	0. 7	101 x 4. 6	9. 24	....
	60	340	4. 9 D.	24	2. 1	122 x 11	10. 94	....
	50	726	9. 1 D.	8	1. 2	41 x 6	13. 39	0. 005
	60	652	8. 4 D.	11	0. 9	56 x 4. 6	15. 01	....
	20	841	0. 8 G.	12	0. 8	61 x 4	7. 79	0. 197
	30	1, 180	14. 1 D.	10	1. 2	51 x 6	12. 28	0. 105
	45	1, 329	15. 3 D.	9	1. 7	46 x 8. 6	17. 26	0. 039
	60	1, 141	44. 3 D.	14	2. 7	71 x 13. 7	21. 93	0. 052
	20	1, 887	9. 0 D.	18	1. 0	91 x 5. 1	11. 87	0. 639
	30	2, 423	17. 8 D.	22	2. 4	111 x 12. 2	17. 22	0. 526
	45	2, 741	59. 0 D.	31	3. 8	157 x 19. 3	24. 41	0. 210
	60	2, 304	73. 7 D.	20	5. 6	101 x 28. 4	29. 24	0. 039
	20	2, 821	14. 3 D.	32	1. 8	162 x 9. 1	14. 87	1. 296
	30	3, 581	23. 7 D.	46	2. 5	233 x 12. 7	21. 39	1. 086
	45	3, 969	47. 5 D.	48	3. 3	243 x 16. 7	29. 91	0. 599
	60	3, 457	97. 9 D.	23	4. 5	117 x 22. 8	36. 11	0. 132
	45	4, 512	....	50	3. 5	217 x 18 Observed.	....	....

Bursting of shells at repose.—Two shells were made to burst at rest, which had been previously fired under an angle of 60°, with charges of 2.240 kilos., and 3.360 kilos.

The shells were placed upon a horizontal block of wood at the bottom of the bursting pits. The covering for the pits consisted of a layer of joists of 32 c. m., connected together and weighted—the first time with a cannon of 1,850 kilos., and the second time with a copper plate of the same weight. The explosion of each of the shells broke the joists of the interior revetment, overturned the covering joists, some of which were broken and projected to some distance, the cannon fell to the bottom of the pit, and some of the fragments of the shells were thrown outside; of the fragments that remained in the pit some were forced into the block of wood 10 c. m.

The following table gives the details relative to these explosions:

Shell.	Weight of empty shells.	Large fragments.				Mean fragments.				Small fragments.	
		No.	Weights.			No.	Weights.			No.	Weights.
			Maximum.	Minimum.	Total.		Maximum.	Minimum.	Total.		
	Kilos.		*Kilos.*	*Kilos.*	*Kilos.*		*Kilos.*	*Kilos.*	*Kilos.*		*Kilos.*
First shell	83. 45	15	12. 300	1. 680	54. 300	15	1. 680	0. 840	31. 800	15	4. 760
Second shell	83. 45	14	12. 300	1. 680	58. 800	10	1. 680	0. 560	12. 040	16	0. 560

To these numbers should be added about 0.100 kilo. of *débris.*

To sum up:

For the first shell, 70 fragments recovered (comprising 11 of the lead coating), weights, 81.200 kilos.

For the second shell, fifty fragments recovered (comprising 5 of the lead coating), weight, 71.700 kilos.

The bottoms remained entire; the point was broken into four or five pieces.

Effects of fire.—To study the effects of the fire of the mortar of 8 pouces, a structure was raised upon the ground of the polygon of Steinfield, which is represented in Plate VIII, *a* and *b*. Two shelters were formed together by three longitudinal walls (in the direction of the fire) 0.95 meters thick, and by a front wall of the same thickness; the two shelters were 10 meters in length, the width of one being 6.30 meters and of the other 4.40 meters. Four different systems of coverings were applied to these shelters, so that there were thus four different forms of casemates represented.

Casemate No. 1.—Covered by means of double T-beams, 31 c. m. in height, with spaces between of about 24 c. m. Upon the lower flanges on the T were placed curved plates of plate iron; the interval between the rails was filled with *béton*, which covered them through a thickness varying from 32 c. m. to 48 c. m.

Casemate No. 3.—Covered by means of iron rails 52 c. m. in height, with spaces of 1.58 meters; between them were brick arches of 48 c. m. The rails rested upon two other rails, serving as supporting plates; upon the arches were laid a bed of *béton*, from 48 c. m. to 32 c. m. in thickness.

Casemate No. 2.—Same covering as in casemate No. 1, except that the rails were not so strong (26 c. m. in height).

For these three casemates, the two rails that serve as plates rested on offsets that projected from the longitudinal walls (32 c. m. in width).

Casemate No. 4.—Covered with joists of 32 c. m. by 42.5; bearing upon plates disposed upon offsets above the joists were two tiers of *saucissons* crossed.

The minimum thickness of the layer of earth that covered the entire shelter was 1.90 meters.

Besides the casemates Nos. 1 and 3, a battery powder magazine was constructed, the roof of which was formed of joists of 21 c. m. by 21, supported by posts 26 c. m. by 26, and covered by two layers of *saucissons* crossed, and 1.30 m. of earth.

The total surface occupied by the group was about 17 meters in the direction of the fire, and 28.50 meters in width. The superfices occupied by the casemates in the clear was 11.06 meters by 13.90 meters.

One hundred and forty-nine shots were fired, in 1870, upon this shelter; 21 shells (15 p. ct. about) hit the group, 9 of which struck the slopes. Of these 21 shells 8 were ballasted but not charged; the 13 others were charged.

The shells not charged, fired under an angle of 60° and at a distance of 2,580 meters, penetrated the covering of earth from 1.75 meters to 1.85 meters.

The first shells charged were armed with instantaneous fuses, and produced craters of about 3 meters in diameter by 95 c. m in depth; under the action of these shots, the registering apparatus, placed under the ceilings of the casemates, showed an oscillation of from 4 to 5 millimeters for the lower surfaces of the arches, and of 2 millimeters for the rails; the largest permanent deformations did not exceed 6 millimeters.

The feebleness of these effects was attributed to the fact that the explosion of the shell took place at the moment of the shock, and experiments were accordingly made with the object of rendering the action of the fuse so slow that the explosion should not be produced till after the shell had attained its penetration. After some trials, satisfactory results were obtained, and the shells were armed with slow fuses.

A shell (No. 16 of the sketch) produced upon casemate No. 1 a crater of 4.20 meters in diameter, which was almost completely filled up again by the falling brick of the earth; two of the iron rails were broken, and six of the curved plates; and a crack 15 c. m. wide was produced in the ceiling. Another shell (No. 19) having attained the ceiling of casemate No. 1, where it joined casemate No. 3, produced a crater of 4.75 meters in diameter by 0.35 meters in depth, with the sinking of a part of the first arch of brick casemate No. 3; the rails which served as plates were forced into the partition wall of the casemates, causing a portion to fall down. The sinking of the arch extended very nearly to the axis of the casemate. (For details see cuts a′, b′, yz and vx, Plate VII [a.b].)

The superiority of the effect of shells with slow fuses was thus well established. The interval between the shock and the explosion of the shell varied from 0.32 second to 1.47 seconds. The little powder magazine was struck by a shell not charged (No. 10), which traversed completely the covering, displaced a post 15 c. m. square, split it, traversed the flooring joists, and buried itself 32 c. m. in the ground.

The following table gives the results of fire of the 21 shells which struck the group of casemates. (On Plate VIII the points of fall of the loaded shells are marked by little circles.)

Number of shots.	Nature of fuse.	Charge.	Angle of fire.	Mean range.	Penetration.	Diameter of crater.	Total amplitude of oscillation of the ceiling of the arch.
		Kilos.	*Deg.*	*Meters.*	*Meters.*		*Millim.*
1 (1)	....	4.2	61	2,845	1.85	....	8
2 and 3 (2)	....	} 2.52	60¼	1,688	1.85	....	....
4 (3)	....						
5 (4)	....	3.692	60	2,586	....	....	....
$6_{\circ}$, $7_{\circ}$, $8_{\circ}$ (5)	Instantaneous	3.692	60	2,586	....	....	....
9 (6)	....	3.692	60	2,586	1.75	....	8
10 (7)	....	3.692	60	2,586	....	....	....
$11_{\circ}$ (8)	(?)	3.692	60	2,586	} 1.70	3.15	10
$12_{\circ}$ (9)	Slow	3.692	60	2,586			
13 (10)	....	3.692	60	2,586	....	....	....
$14_{\circ}$, $15_{\circ}$ (10)	Slow	3.692	60	2,586	....	....	....
$16_{\circ}$ (11)	....do	3.692	60	2,586	....	4.20	....
$17_{\circ}$ (12)	....do	3.692	60	2,586	....	....	....
$18_{\circ}$ (12)	....do	3.692	60	2,586	0.55	3.80	....
$19_{\circ}$ (13)	....do	3.692	60	2,586	0.35	4.75	....
$20_{\circ}$ (14)	....do	3.692	60	2,586	....	....	....
$21_{\circ}$ (15)	....do	3.692	60	2,586	....	....	....

(1) Struck the middle of casemate No. 3 without serious effect.
(2) Struck the front slope without causing injury.
(3) Struck on casemate 2 against the front wall, and forced itself into the upper row of bricks 6 c. m.
(4) Struck the front slope without doing injury.
(5) Burst in the slope without other damage.
(6) Struck upon casemate No. 1 near the front wall, causing a permanent depression of 2 m. m.
(7) Traversed the ceiling of the little magazine, displaced a post, and buried itself 32 c. m. in the earth.
(8) Struck casemate 3 and produced but little disturbance.
(9) Struck alongside of the preceding and produced a fissure 3 m. in length by 1 m. m. in width.
(10) Struck upon the slope with the usual effect.
(11) Struck on casemate 1, crater refilled, 2 posts broken, 5 curved pieces of 2 c. m. cracked 15 c. m. in width.
(12) Burst in the slope.
(13) Fell upon casemate 3; degradations represented on Plate VIII.
(14) Struck the edge of casemate 3, projecting some fragments and some bricks as far as the front slope.
(15) Burst in the mass of earth of the little magazine.

In summing up these effects it will be seen that it is possible with the mortar of 8 pouces, fired under an angle of 60° at a range of 2,500 meters, to group a considerable number of shots upon a restricted surface, and that under these conditions of fire the effects are very formidable upon casemate covers, the ceilings of which have 1 meter of thickness of brick

and béton, covered over with 2 meters of earth; the cross traverses of our fortifications would not resist this fire.

The experiments at Steinfeld teach us nothing as to the effects of the fire against arches of masonry, similar to those of our great powder-magazines; it is probable that these arches would resist isolated shots, but would be too feeble to sustain the effect of a number of shots luckily grouped. Again, upon butts presenting such large surfaces as these magazines, the firing would take place at a greater distance, by which more powerful effects would be obtained. The table of the results of the firing teaches, in fact, that under an angle of 60°, and at 3,500 meters, the rectangle circumscribed by 25 per cent. of the shots has for its dimensions about 30 meters by 4 meters, and finally, under an angle of 45°, and at a range of 4,500 meters, 25 per cent. of the shots would fall in a rectangle of 42.5 meters by 3.25 meters.

The Austrians have concluded from their experiments that the arches ought to be covered with not less than 2.50 meters of earth, and that the craters ought to be filled up with care. They are equally of the opinion that blindages with iron posts and rails are not of a great deal of value; that blindages of rails especially are only capable of resistance when formed of rails little strained, joined, well supported against pieces of wood, with a maximum span of 2.50 meters, and covered with at least 2.50 meters of earth.

Degradations of the piece.—We shall terminate this study of the mortar of 8 pouces by showing the manner in which the piece has sustained the effect of long-continued firing.

A mortar having received the different modifications, details of which have been described, was fired 691 shots, 460 of which were with large charges of 6 livres (3.360 kilos.); the degradations ascertained were as follows:

The rifling showed the imprint of the shocks of the fuse-pins, which were detached at first (this defect was remedied during the experiments). Apart from that the edges were very little worn, and no traces were visible, either of leading or of degradation from the gas. In the unrifled portion some porosities were detected, and some furrows in which a great many small cavities were recognized, the greatest of which had a diameter of 4 m. m. and a depth of 1 m. m. The recess of the obturator was perfectly even.

The enlargement of the rifled part of the bore was 0.18 m. m.; that of the unrifled part varied from 0.55 m. m. to 0.18 m. m. in proceeding from the recess of the ring to the conical junction.

The end of the vent-bush was disjointed on the interior by a width of 1.3 m. m., but was well united on the exterior; the diameter on the exterior was 9.5 m. m.; on the interior 13.2 m. m.

The supporting plate of the ring carried by the coin showed some scoring. The system of fermeture was well preserved in all its parts.

Upon the whole, the degradations were of little importance; the most serious was that of the vent.

5. AUSTRIAN RIFLED MORTAR OF 6½ POUCES (182 M. M.)

The excellent results obtained with the mortar of 8 pouces induced the Austrians to construct another on the same system, but of a less caliber, for the purpose of firing against shelters less resistant.

The weight of the loaded shell for this piece is about 33.5 kilos.; that of the interior charge, 3.130 kilos. A carriage was also provided, which allowed of firing under small angles. Some experiments have been made with incendiary shells, the results of which are unknown to us; but

the experiments with illumined projectiles (light-balls) have been successful.

The following table gives some of the results of the firing with this mortar, the accuracy of which is remarkable.

Fire of the Austrian mortar of 6¼ pouces (182 *m. m.*).

Charges.	Angles.	Ranges.	Mean deviation.		Width of belts, of an indefinite length, containing 50 per cent. of the shots. (Sides of the rectangle containing 25 per cent.)	
			Longitudinal.	Lateral.	Longitudinal.	Transversely.
Kilograms.	*Degrees.*	*Meters.*	*Meters.*	*Meters.*	*Meters.*	*Meters.*
0.450	50	548	28.3	1.8	48.0	3.1
	60	469	16.1	2.6	27.3	4.3
	70	324	20.5	2.3	34.3	3.7
0.900	30	1,309	13.7	1.7	22.8	2.8
	45	1,482	22.9	3.0	38 2	5.0
	60	1,262	13.2	1.6	21.9	2.6
	70	937	15.0	10.0	25.0	16.7
1.350	30	2,053	30.8	3.0	50.5	5.0
	45	2,248	24.0	2.7	40.0	4.5
	60	1,911	22.8	4.3	38.0	7.2
	70	1,408	17.9	4.7	29.8	7.8
1.800	30	2,804	23.3	4.0	38.7	6.7
	45	3,095	33.1	4.3	55.2	7.1
	60	2,645	25.3	3.5	42.2	5.8
	70	1,936	23.8	6.5	39.7	11.0
2.250	3	607	5.8	1.1	9.6	1.8
	10	1,651	13.2	1.6	21.9	2.7
	20	2,761	21.8	3.1	36.2	5.1
	30	3,566	30.7	3.8	51.1	6.3
	45	3,968	28.3	5.3	47.0	8.7
	60	3,443	51.2	14.5	85.3	24.3
	70	2,448	20.0	8.7	48.3	14.4

RÉSUMÉ AND CONCLUSIONS.

Comparison of the different pieces examined.

It appears from the preceding examination that the principal European artilleries have produced rifled howitzers and mortars throwing shells of 80 kilos. with sufficient accuracy to render them formidable to covered arches or blinds, such as exist at the present.

Following are some elements for a comparison of these different pieces:

Elements.	France.	England.	Prussia.	Austria.
	Howitzer of 22 c. m.	Howitzer of 8 inch.	Mortar of 21 c. m.	Mortar of 8 po.
Nature of the metal of the piece	Cast iron, banded.	Wrought iron with steel tube.	Bronze	Cast iron.
Method of loading	Muzzle	Muzzle	Breech	Breech.
Caliber of the bore ... millimeters	223.3	203.2	209.3	209.3
Length of rifled portion (in calibers)	9.8	4.4	5.5	4.1
Number of grooves	3	4	30	30
Twist (in calibers), about	....	16	25	60
Inclination of the grooves to the generatrices of the bore.	0° to 6°	11° 6′ 31″	7°	3° 1′ 16″
Weight of the piece ... kilos	3,700	2,350	3,025	4,655
Weight of the loaded shell	79.8	81.4	80.0	87.0
Weight of the interior charge of shell	4.0	5.9	5.0	4.0
Maximum firing-charge	6.0	4.53	3.5	5.6
Ratio of the weight of the maximum charge to the weight of the projectile.	1 to 13	1 to 18	1 to 23	1 to 13
Ratio of the weight of the projectile to the weight of the piece.	1 to 46	1 to 29	1 to 38	1 to 53
Maximum initial velocity ... meters.	257	....	215	
Maximum range ... do.	5,220	4,480	4,000	4,500

It will be seen from this table that the French howitzer and the Austrian mortar of 8 po. permit of the attainment of the greatest ranges, but also that their weights are very considerable; the Austrian mortar, particularly, appears to have an exaggerated weight relatively to the effects attainable with it; it is possible by the system of banding to reduce this weight, say, at least, 800 kilos., and to give the piece a greater length of bore, which would permit the use of larger charges and of a more progressive powder, by means of which ranges of 5,000 meters should be obtained.

In order to compare the accuracy of fire, we have calculated the ratios of R and ρ of the mean deviations, longitudinal and lateral, to the ranges. The following table indicates the limits between which these ratios vary for the different angles of fire, in proportion as the ranges increase:

Piece.	30°.		40°.		45°.		60°.	
	R	ρ	R	ρ	R	ρ	R	ρ
French howitzer of 22 c. m.	$\frac{1}{37}$ to $\frac{1}{87}$	$\frac{1}{315}$ to $\frac{1}{365}$	$\frac{1}{40}$ to $\frac{1}{66}$	$\frac{1}{450}$ to $\frac{1}{365}$				
English howitzer of 8 inches.*	$\frac{1}{55}$ to $\frac{1}{155}$	$\frac{1}{550}$ to $\frac{1}{1400}$	$\frac{1}{44}$ to $\frac{1}{330}$	$\frac{1}{194}$ to $\frac{1}{1436}$				
Prussian mortar of 21 c. m.	$\frac{1}{575}$ to $\frac{1}{364}$	$\frac{1}{575}$ to $\frac{1}{565}$	....	....	$\frac{1}{155}$ to $\frac{1}{321}$	$\frac{1}{1555}$ to $\frac{1}{413}$	$\frac{1}{255}$	$\frac{1}{435}$
Austrian mortar of 8 po.	$\frac{1}{125}$ to $\frac{1}{75}$	$\frac{1}{560}$ to $\frac{1}{1433}$	....	....	$\frac{1}{125}$ to $\frac{1}{75}$	$\frac{1}{760}$ to $\frac{1}{1433}$	$\frac{1}{81}$ to $\frac{1}{180}$	$\frac{1}{411}$ to $\frac{1}{785}$
Austrian mortar of 6⅓ po.	$\frac{1}{55}$ to $\frac{1}{125}$	$\frac{1}{770}$ to $\frac{1}{535}$	....	....	$\frac{1}{55}$ to $\frac{1}{120}$	$\frac{1}{400}$ to $\frac{1}{535}$	$\frac{1}{67}$ to $\frac{1}{124}$	$\frac{1}{715}$ to $\frac{1}{535}$

*A 20°, R = $\frac{1}{34}$ to $\frac{1}{261}$; ρ = $\frac{1}{330}$ to $\frac{1}{1700}$.

It will be seen, from a study of the figures in this table, that the French howitzer has above all a notable inferiority in point of accuracy of range. The Prussian mortar (as far as we are able to judge from the limited information at our disposal) has a sensible superiority over the Austrian mortar in point of accuracy of range; but the accuracy in direction of the Austrian mortar is very much greater than the Prussian. This latter fact would tend to prove that the Prussians, notwithstanding the modifications successfully introduced in the plan of their shell, have not yet succeeded in giving to it a stability upon its trajectory comparable to that of the Austrian shell. In respect to this, however, it should be observed that the inclination of the rifling in the Prussian mortar is 7°, while in the Austrian mortar the inclination is only 3°; it is generally admitted in France that the inclination of the rifling for large pieces should but little exceed 4°.

In respect to the effects of fire, the difference of weights of projectiles thrown by the pieces examined is too small to give rise to the supposition that there would be any appreciable difference in the effects of penetration for the same angles of fire and the same ranges; in point of the effects of explosion, the English shell, owing to its greater bursting charge, ought to be the most powerful.

Conclusions.—From what precedes it is to be concluded that the French howitzer, which was remarkable enough at the time of its adoption, has not to-day a sufficiently accurate fire to warrant its introduction into siege-trains; for the armament of places, and the provisional armament of coast-batteries, it may possibly do good service, because, in these two cases, the effects of isolated shots may be very formidable, notwithstanding that, in order to obtain serious effects against the very solidly constructed shelters of a place, it is necessary to group the shots upon a

small surface; the preceding experiments which we have detailed show, in fact, that we cannot count on very complete results against shelters solidly constructed, if we are not able to remove by the explosion of some of the shells the mattresses of earth which cover the arches.

STUDY OF A RIFLED MORTAR OF 21 C. M.

It is fitting, then, in France, to take into consideration the construction of a rifled howitzer or mortar of 21 c. m., of cast iron, banded, or of bronze, throwing a shell of about 80 kilos. weight with an interior charge of 5 kilos., as near as may be possible. This piece should weigh about 3,500 kilos. The rifled portion of the bore should be 5 calibers in length, and the piece be loaded by the breech, in order to give the shell sufficient stability upon its trajectory, which can only be obtained in a short piece by exact centering of the projectile, an end much less difficult to obtain in a cannon loaded by the breech than in one loaded by the muzzle.

With the length of bore indicated, a firing-charge of 6 kilos. could probably be utilized, and of a powder of sufficient high density, with medium-sized grains, to give promise of ranges exceeding 5,000 meters.

The twist of the 24 cuneiform grooves should be about 1 turn in 30 calibers.

As to the system of fermeture, the cylindro-prismatic coin would be most advantageously employed.*

The obturator should be of copper or of brass; it would be well, if precise information could be obtained, to make a trial of the Austrian obturator, which appears to have given the best results.

In employing cast iron for the fabrication of the piece the shells could be fitted with bands of copper or of zinc; if bronze should be employed, the bands should be of lead; the plan of the chamber for the projectile adopted for the cannon of the marine (mod. 1870) would be well suited to either of these two systems of banding projectiles.

To communicate fire to the bursting charge of the projectile a fuse of double reaction should be employed, such as has been previously described for the shell of 22 c. m.; it would, however, be necessary to devise some modification, by which the explosion of the shell should not take place until its penetration was completed; this result would probably be attained by charging the primer of the percussion apparatus with composition, or with priming powder instead of sporting powder.

Finally, it would be necessary to study the possibility of firing a projectile with a solid head of chilled iron, especially designed to pierce the coverings of armored cupolas and the decks of iron-clad ships.

The carriage for the howitzer should be of plate-iron, of a form similar to those of the marine, with axle-brackets carrying to 1.60 m. the height of the axis of the trunnions, in such manner as to permit of firing under the greatest angle. The piece having a very slight breech preponderance with the projectile in place, a controlling lever would suffice to hold it in all positions. The supports for the trunnions should be of bronze, similar to those of the siege-carriage of 24 c. m. The movements of the carriage upon its platform would be facilitated by the employment of eccentric rollers, upon sleeves solidly attached. To give the direction to the fire, it would be necessary to furnish the carriage with an apparatus for indirect pointing, similar to that of the Prussian siege-carriages

* The preference is given to the cylindro-prismatic coin over the screw fermeture of the marine, because it is feared that the latter would behave badly with a quick powder.

(*Revue*, tome III, p. 2). The total weight of the carriage would be 2,500 kilos.

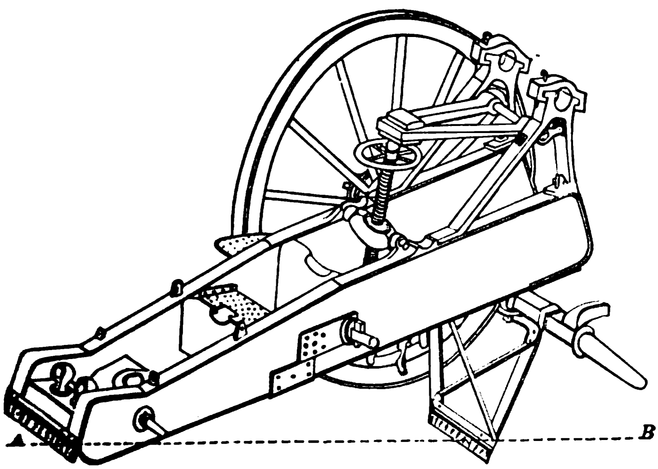
A carriage of this kind would only permit of firing under great angles; if it is desired to employ the howitzer in direct fire, it would be necessary to adopt a carriage admitting of a greater height of genouillère, such as that of the Italian siege-howitzer, described in the article of Captain Manceron (January, 1873, page 311). The fire under small angles is, however, of a doubtful utility for a piece of this kind.

It would hardly be practicable to transport such a piece upon its carriage; it would seem preferable to transport the piece and its carriage separately, each upon a platform wagon. With the trench-gin the piece could then be mounted, in the battery itself, upon a carriage of the model indicated. The platform ought to be very solid; it should be formed of 4 strong sleepers supporting a flooring of joists 2.60 m. in length and 22 c. m. square.

APPENDIX.

The apparatus for indirect pointing employed by the Prussians in the sieges of the war of 1870–1871 is thus described in the *Revue* (tome III, page 2):

The apparatus is composed, 1st, of a trapezoidal frame of iron attached to the axle by means of straps; under the lower side, and parallel thereto, is fixed a graduated plate



of brass. When the frame is lowered, the graduated plate touches the platform; but when not required for use it is raised up and secured by hooking it to some rings on the under side of the cheeks. 2d, of a plate similar in form and graduation to the one already mentioned, which is attached to the butt-end of the trail; when the latter is lowered, this plate, like the other, comes in contact with the platform. The plate turns on a hinge, and may be raised up and fastened to a spring-hook on the rear transom.

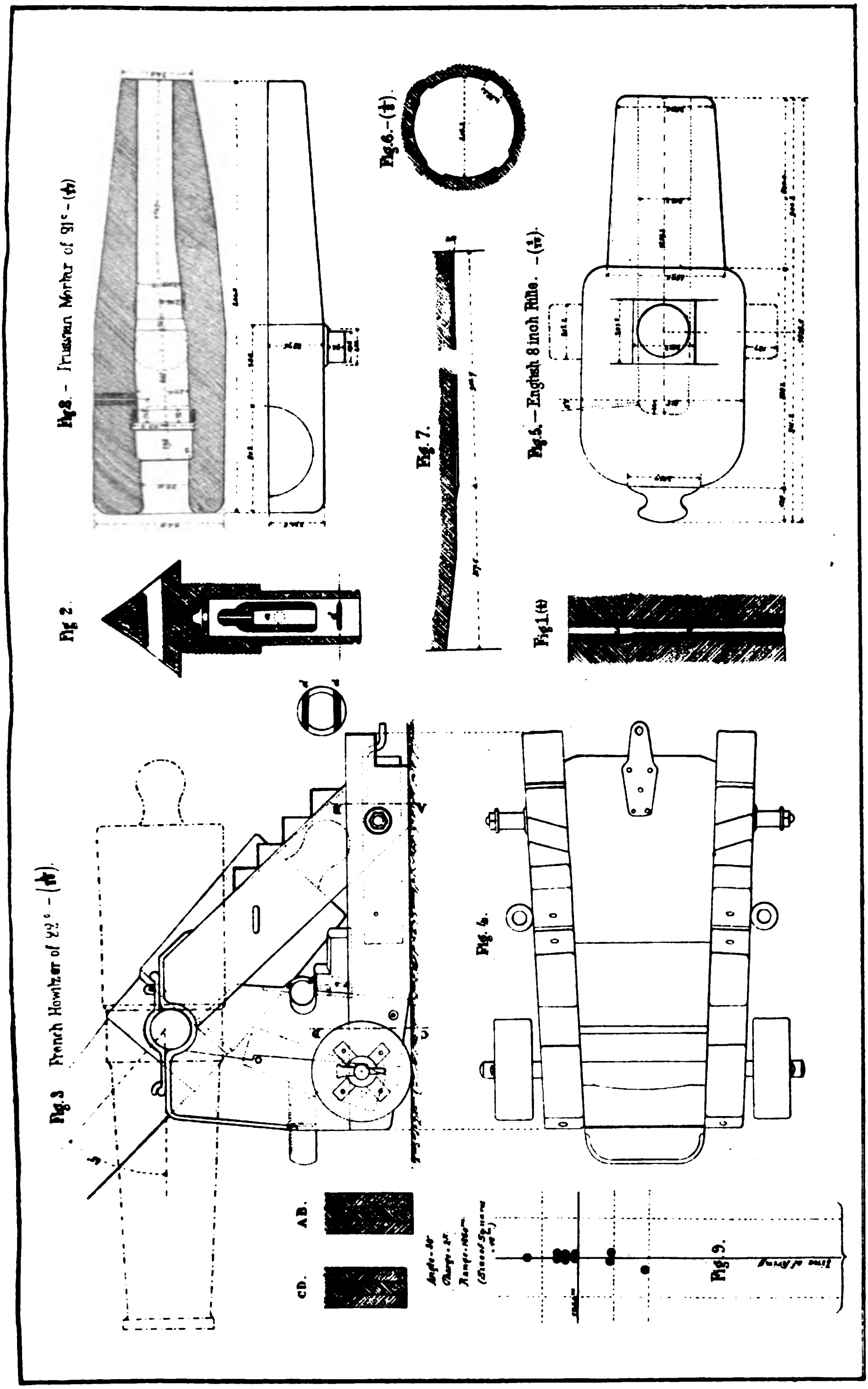
In using this apparatus it is operated as follows: The fire being once suitably adjusted by means of direct observations, the difference which exists between the graduations of the two plates is noted, the readings being made from the zero to the directrix, A, B, traced upon the platform.

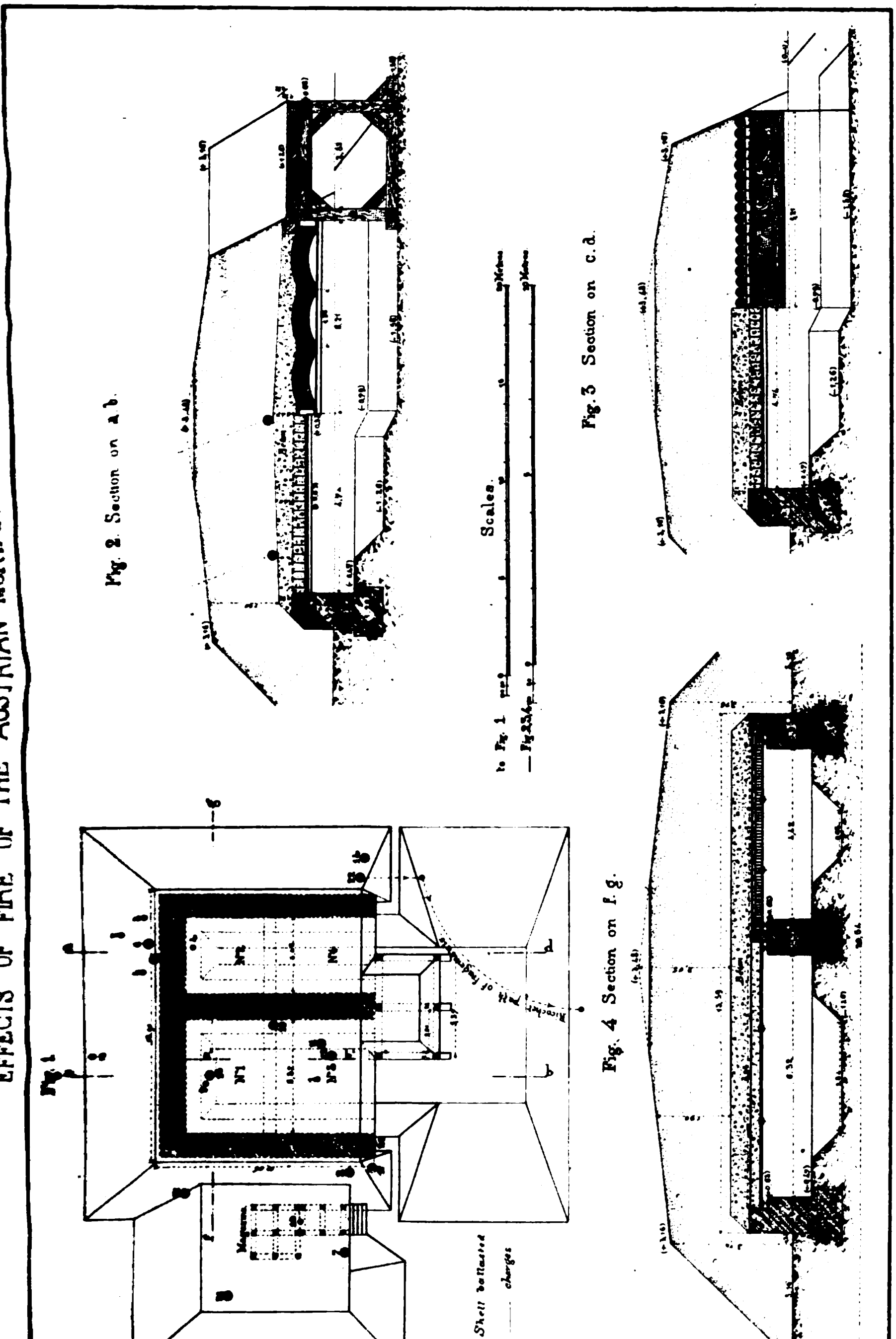
In all the firing that follows it suffices, in order to point the piece, to read the graduation of the first plate that coincides with the directrix, and then to shift the trail to the right or left until the difference between the graduations of the plates shall be

equal to that originally noted. The graduation of the plate is arbitrary. In the Prussian artillery the principal divisions are 40 m. m. apart, and these intervals subdivided into 10 equal parts.

These graduated scales permit of maintaining with great exactness, and without renewed pointing, a line of sight once established, which is of the greatest importance in firing at an object concealed from the view; they also permit of varying, laterally, the point of fall for all distances, by displacing horizontally the point of departure of the line of sight, an operation required in breeching masonry, for making the horizontal cut.

This method of pointing was employed by the Prussians with great success at the siege of Strasbourg, in batteries without embrasures, for breeching walls of masonry by a plunging fire.


RIFLED HOWITZERS AND MORTARS.
Fig. 3. French Howitzer of 22c.
Fig 2.
Fig. 8. Prussian Mortar of 21c.
Fig. 6.
Fig. 7.
Fig. 5. English 8 inch Rifle.
Fig. 1.
Fig. 4.
AB.
CD.
Fig. 9.



Accompanying Appendix L. 1878

Fig. 12.

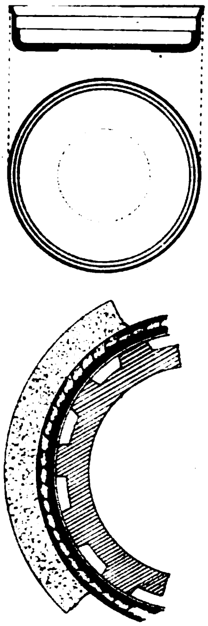


Fig. 11.

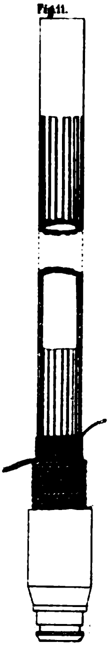
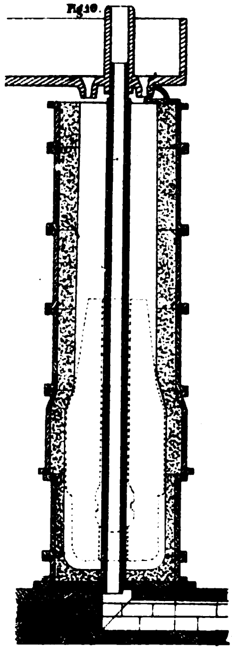


Fig. 10.



Cheek bracket.

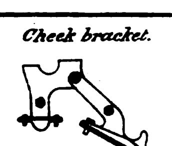
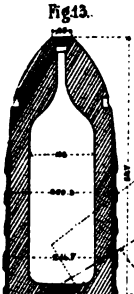
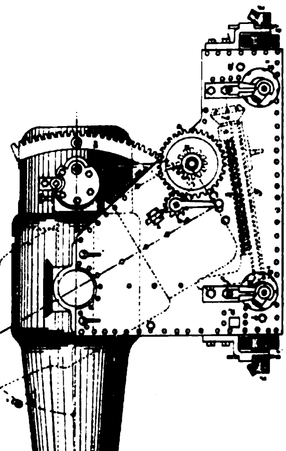


Fig. 13.





EXPERIMENTS EXECUTED AT POLYGONE OF STEINFELD

Fig. 5. Section on a'b'

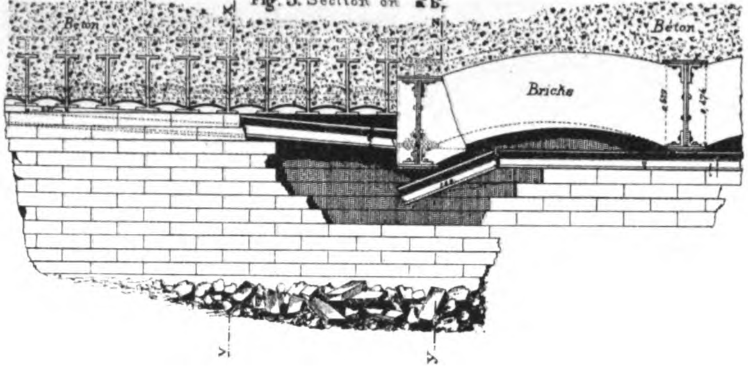


Fig. 7. Section yz.

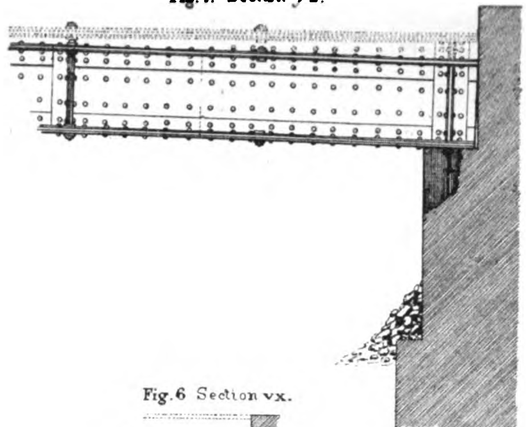


Fig. 6 Section vx.

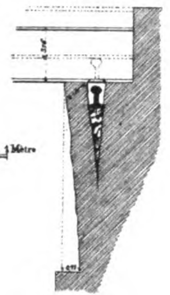
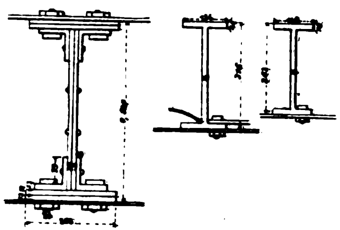


Fig. 8 Section of iron beams. (⅒)



Scale.

APPENDIX N.

RECOIL DYNAMOMETERS, BY FIRST LIEUTENANT HENRY METCALFE, ORDNANCE DEPARTMENT, UNITED STATES ARMY.

(One plate.)

FRANKFORD ARSENAL,
May 18, 1878.

I have for some time thought that the present manner of measuring the recoils of small-arms was susceptible of some improvement, by which the great differences of record, due solely to changes of dynamometer, could be eliminated and really consistent indications obtained.

As a case in point I need only cite the pamphlet on small-arms in the United States service, Springfield, 1875, where the recoil of the rifle is given at 174 pounds. In the Report of the Chief of Ordnance, 1873, p. 403, it is given at 123.6 pounds, and in the dynamometer at present employed it is placed at about 95 pounds, about one-half that first cited.

These differences, due simply to the use of springs of different stiffness for measuring the same effect, are so contradictory that one can hardly be surprised at the amount of discussion they have led to, notably in the case of Captain O'Hea with the British war office on the subject of muzzle rifling. (See Proceedings of the United Service Institution, 1874 or 1875.)

With this idea in view it occurred to me in 1875 to abolish all differences due to the variations in the springs usually employed, by dispensing with them altogether, substituting for them a material of universally uniform resistance, such as copper or lead, and measuring the recoil by means of a cut made in the material by a Rodman knife interposed between the metal and the butt of the gun, in the manner shown in Fig. 2. The apparatus was slipped into the spring-holder shown in Ordnance Note XXXI. The spring dynamometer therein described was used in comparison with it.

With the service rifle and ammunition cuts were obtained corresponding to a pressure of about 1,900 pounds.

Now, according to the generally received method of expressing the "recoil" statically, this measure of 1,900 pounds is as truthful a one as that of one 174, 123.6, or 95 pounds, obtained by determining the "dead weight" necessary to compress the dynamometer spring to the same extent as that due to the recoil of the gun. This enormous and insupportable weight, fairly deduced from the prevailing theory, shows its absurdity.

I have since thought of a hypothesis by which these data may be reconciled, and which may be thus announced:

The gun in recoiling against any known dynamometer *moves*, and hence acquires "*vis viva*," the measure for which should be in dynamical units, representing the work the gun performs by its inertia. Preferably this should all be expended on the dynamometer, where it can be recorded; but, practically, part of it is expended on the gun itself by its change of form in consequence of the resistance of the dynamometer.

Generally speaking, the stiffer the dynamometer spring the more will the gun-stock, mechanism, &c., be distorted and heated by the blow.

Hence, to record the full effect of the recoil, the gun should be as incompressible and the dynamometer as flexible as possible.

Except for convenience, it should be disposed with as a material obstacle, and the gun be made to lift its own weight, as in the gun-pendulum.

In other words, no recoil dynamometer is necessary, since all the information it imparts can be deduced from the initial velocity of the bullet, its mass, and that of the gun.

Should a dynamometer with a spring be used, the scale-stem should be graduated in *foot-pounds* expressing the work done in compressing the spring to different degrees. To graduate it in *pounds* is as incorrect as to graduate it in *inches* and to express the recoil in terms of a foot. For, with the same spring, inches and pounds are convertible; and the prevailing theory requires that the same or equal springs shall be used. To show what errors this may lead one into, I need only recall the fact that, owing to the difference in the temper of the spring of the dynamometer recently made here for the National Armory, it was found necessary, by agreement with Colonel Benton, to falsify the scale of pressures so as to obtain similar numerical results here and at that post.

If the dynamic theory be adopted how simple it all becomes.

Supposing that in the spring the resistance varies directly with the degree of compression—which is practically true—the quantity of work required to compress the spring to any degree is given by the formula

$$Q = C\frac{a^2}{2} \qquad (1)$$

Bartlett, p. 39, edition 1858. In which C denotes the resistance of the spring when compressed through a distance unity, and a denotes the observed degree of compression.

Owing to the relation between the resistance and compression the curve connecting the resistance with the path is a straight line, inclined to the axis on which the compressions are laid off at an angle whose tangent = C. See Fig. 1.

The area included between this line, the axis of abscissas, and the ordinate at any point on that axis, measures the work done in compressing the spring to that point.

For example: let $C = 32$ pounds and $a = 3$ inches; then from the triangle

$$Q = \frac{1}{2}(96 \times 3) = \frac{288}{2} = 144 \text{ inches-pounds} = 12 \text{ foot-pounds.}$$

Or from the formula $Q = C\frac{a^2}{2}$, $Q = 32\frac{9}{2} = 144$ inch-pounds = 12 foot-pounds.

Then, if the quantity of motion given to the gun by the force impressing an equal quantity of motion on the bullet imparts to it a velocity of recoil capable of developing a living force = 24 foot-pounds = 2 Q, the spring will be compressed either 3 inches, or to the 96-pound *mark*, according to the graduation adopted.

This is supposing that there is no loss of effective work due to the distortion of the gun, &c., and that there is no initial tension.

Suppose that there is an initial tension to the 50-pound *mark*, the spring is compressed to that extent by hand before the gun is fired, *i. e.*, so much of its work is done for it beforehand. Does this relieve it of its task? By no means. So to speak, it merely transfers the bench-mark

to a higher level, and the area expressing the work of the recoil becomes trapezoidal instead of triangular; consequently, the greater the initial tension the less distance will the slide move along the scale-stem for the same recoil, but the work its movement covers will be the same. The recoil which with no initial tension moved the slide from 0—3 will now only move it from d to a point e, so taken that the area $3\ e\ g\ f =$ triangle $0\ d\ h$, or $0\ 3\ f = d\ e\ g\ h$.

It is consequently impossible theoretically to get the tension so high as to prevent any movement whatever of the slide; practically so, too, until the resistance becomes practically infinitely greater than that of the gun-stock to distortion.

To prove this, I fired a rifle with 20 grains of powder and one service bullet against an initial tension of fifty pounds.

Inasmuch as the accepted measure of the recoil with 70 grains is 95 pounds, this charge should give a result about $\frac{2}{7}$ as much, or say 30 pounds—far within the limits of the initial tension. Consequently, under the existing theory there should be no recoil indicated.

On trial, however, I obtained recoils from 56—62 pounds, corresponding to compressions 0''.215—0''.365.

With the same charge, and with the spring set at an initial tension of 90 pounds, three times the estimated *pressure* of the recoil, I obtained a recoil measured by the scale of 95 pounds, compression 0''.168.

The success of the experiment led me to carry it further by firing with 10 grains of powder against initial tensions of 50 and 90 pounds.

The recorded recoils were respectively 52 and 91 pounds, measuring about 0''.07 and 0''.05 compressions.

The value of these recoils computed dynamically are, for the 20-grain at 50 and 90 pounds tensions, respectively, 1.208 and 1.347 foot-pounds.

For the 10-grain charge the values are 0.316 and 0.394 foot-pound. The corresponding velocities were too low to be conveniently taken.

These values and those hereafter given are only approximate, owing to the difficulty of measuring the small degrees of compression without special instruments. They serve, however, to illustrate the principle involved.

Which method is the more rational—a mode of measurement which for the same gun and cartridge gives the same or nearly the same result, whatever the accidental peculiarities of the spring may be, and which gives results reasonably comparable with each other, when the conditions differ; or a system which, taking no heed of initial tension extraneously produced, gives for precisely the same recoil a measured *pressure* of either 95 or 115 pounds, according to the initial tension which may have be enselected (see Table I, *post*), and which may be so arranged as to give for 20 grains of powder the same *pressure* given for 70 grains, viz. 95 *pounds?*

We are told that these recoils in pounds, though not absolutely correct, yet are comparative; this I deny. Take indicated recoils of 90 and 100 pounds. If these can be compared in any but the broadest sense, viz, that one is somewhat greater than the other, the scale-marks mean that there is a difference between them of 10 per cent. of the greater one. A moment's consideration of the triangle of work, Fig. 1, will show this to be untrue. The real difference is nearly 25 per cent.

If, then, this mode of measurement is neither absolute nor comparative, what is it good for?

I would respectfully recommend that the three dynamometers now in service be altered to receive springs with no initial tensions, and that the scale-stems be graduated in foot-pounds.

EXPERIMENTS.

In order to make the investigation as complete as possible, I have fired the service rifle and carbine with their own and each other's ammunition, both for initial velocity and recoil; varying the initial tension from 50—90 pounds by slipping washers of suitable thickness around the slide-stem of the recoil apparatus.

The results are given in the accompanying Table I.

The velocities were obtained for use with the formula herewith deduced.

Let m w and v and M W and V represent the mass, weight in pounds, and initial velocity of the bullet and gun respectively, then—

$$m\,v = \mathrm{M\,V},$$

$$\text{or } \mathrm{V} = \frac{m}{\mathrm{M}}\,v = \frac{w}{\mathrm{W}}\,v.$$

$$\text{But the work of recoil} = \mathrm{Q} = \frac{\mathrm{M\,V}^2}{2} = \frac{\mathrm{W}}{2g}\mathrm{V}^2$$

substituting the above value of V,

$$\mathrm{Q} = \frac{w^2 v^2}{2g\mathrm{W}} \qquad (2)$$

Let $w = \frac{405}{7000}$ pounds.

For the rifle let W = 9 pounds; and for rifle ammunition let $v = 1320$ feet; and for carbine ammunition let $v = 1172$ feet.

For the carbine let W = 7 pounds; and for rifle ammunition let $v = 1260$ feet; and for carbine ammunition let $v = 1113$ feet.

(NOTE.—The ammunition for both recoils and pressures was prepared at the same time, from weighed charges of the same lot of powder, Hazard's. The guns were weighed carefully, and were not changed throughout the experiment.)

Supplying the data in equation 2, we get the following quantities of work of recoil:

For the rifle, with the rifle cartridge, 10.077 foot-pounds.
with the carbine cartridge, 7.94 foot-pounds.

For the carbine, with the rifle cartridge, 11.805 foot-pounds.
with the carbine cartridge, 9.211 foot-pounds.

It is found that the compression of the spring in service here, from 0—50 pounds, is 1″.65; and from 50—110 pounds = 1″.88. Total compression, 3″.53. This divided by 110 gives C = 32.1 pounds.

Applying equation 1 to this case, we find the work done in producing the initial tension, by compressing the spring to the 50-lb. mark = 3.641 foot-pounds.

If the spring be set at the 60-lb. mark, $a = 1''.65 + 0''.315 = 1''.965$, and Q = 5.165 foot-pounds;

If at the 70-lb. mark, $a = 2''.28$ and Q = 6.953 foot-pounds;

If at the 80-lb. mark, $a = 2''.595$ and Q = 9.007 foot-pounds;

If at the 90-lb. mark, $a = 2''.91$ and Q = 11.325 foot-pounds.

For any observed recoil we add the measured compression to the initial compression and obtain the corresponding quantity of work. From this deduct the work done by the initial compression, and the result will be the indicated work of the recoil. This will never be fully equal to the actual work of the recoil, since part of it is rendered non-effective, as before explained. This loss will increase with the severity of the recoil; as in firing rifle cartridges from the carbine or rifle, since the resistance of the gun-stock remains unchanged.

It will also increase with the initial tension.

On the other hand, with an absolutely slight recoil, as from the carbine cartridge in the rifle, only slight differences might be expected from even considerable variations of initial tension.

TABLE I.

Arm.	Ammunition.	Theoretical work of recoil in foot-pounds.	Initial tension, pounds.	Mean of number of fires.	Mean readings. Pounds.	Mean readings. Inches of compression.	Mean indicated work of recoil in foot-pounds.	Shock value of equivalent compression in foot-pounds, by Table II.
Rifle	Rifle	10.077	50	5	94.8	1.38	8.67	12.75
			60	3	99.9	1.20	8.28	
			70	2	108.0	1.21	9.34	
			80	3	109.6	0.92	7.52	
			90	1	115.0	0.75	6.60	
	Carbine	7.94	50	5	85.6	1.09	6.42	9.5
			60	3	91.3	0.969	6.35	
			70	3	98.6	0.899	6.57	
			80	3	106.0	0.806	6.46	
			90	3	115.0	0.725	6.34	
Carbine	Rifle	11.805	50	5	98.0	1.519	9.78	14.5
			60	3	103.6	1.363	9.65	
			70	3	108.0	1.210	9.34	
			80	3	110.3	0.967	7.95	
			90	3	115.3	0.756	6.65	
	Carbine	9.211	50	8	86.75	1.206	7.18	10.25
			60	3	94.3	1.089	7.30	
			70	2	102.0	1.00	7.44	
			80	2	107.0	0.85	6.91	
			90	1	116.0	0.74	6.49	

This shows that the lower the tension the nearer the readings get to representing the actual work of the recoil.

This may be shown conversely by increasing the initial tension to a very high point, as in using a copper disk instead of the spring, and measuring its change of form by the Rodman method. (Fig. 2.)

By a somewhat tedious process, which I need not fully explain, I was able to determine the work done in making cuts in the copper corresponding to those inflicted by the recoil.

The penetrations were calculated for a cutter radius$=1''.5$; from them a curve of resistances was laid off, and its area taken at the given points.

The curve expressing the relation between the penetrations and the pressures was approximately a straight line.

TABLE II.—*Measurement of recoils by Rodman knife, &c.*

Arm.	Ammunition.	Theoretical work of recoil in foot-pounds.	Length of cut, 2 sin ϕ (R=1.5).	Ver-sin ϕ	Corresponding pressure, pounds.	Indicated work of recoil in foot-pounds.	Shock value of cut in foot-pounds by experiment.
Rifle	Rifle	10.077	0''.6776	0''.0390	1900	3.66	4.75
	Carbine	7.94	0''.6386	0''.0340	1600	2.69	3.75
Carbine	Rifle	11.805	0''.6968	0''.041	2000	4.0	5.3
	Carbine	9.211	0''.6546	0''.036	1725	3.12	4.2

The last column gives the value of a blow from a falling weight, which made a cut of the same length as that of which the dynamical equivalent had been calculated by the method above referred to.

The same method of verifying the deductions from the compression of the spring was adopted.

Seven and nine pound weights were dropped from different heights on the recoil-spring set at an initial tension of 50 pounds. For the results see table I.

It will be observed that the shock values with the spring bear to the indicated work of the recoil very uniformly the ratio of 1.45 : 1.0.

With the copper the ratio is 1.34 : 1.0 very uniformly.

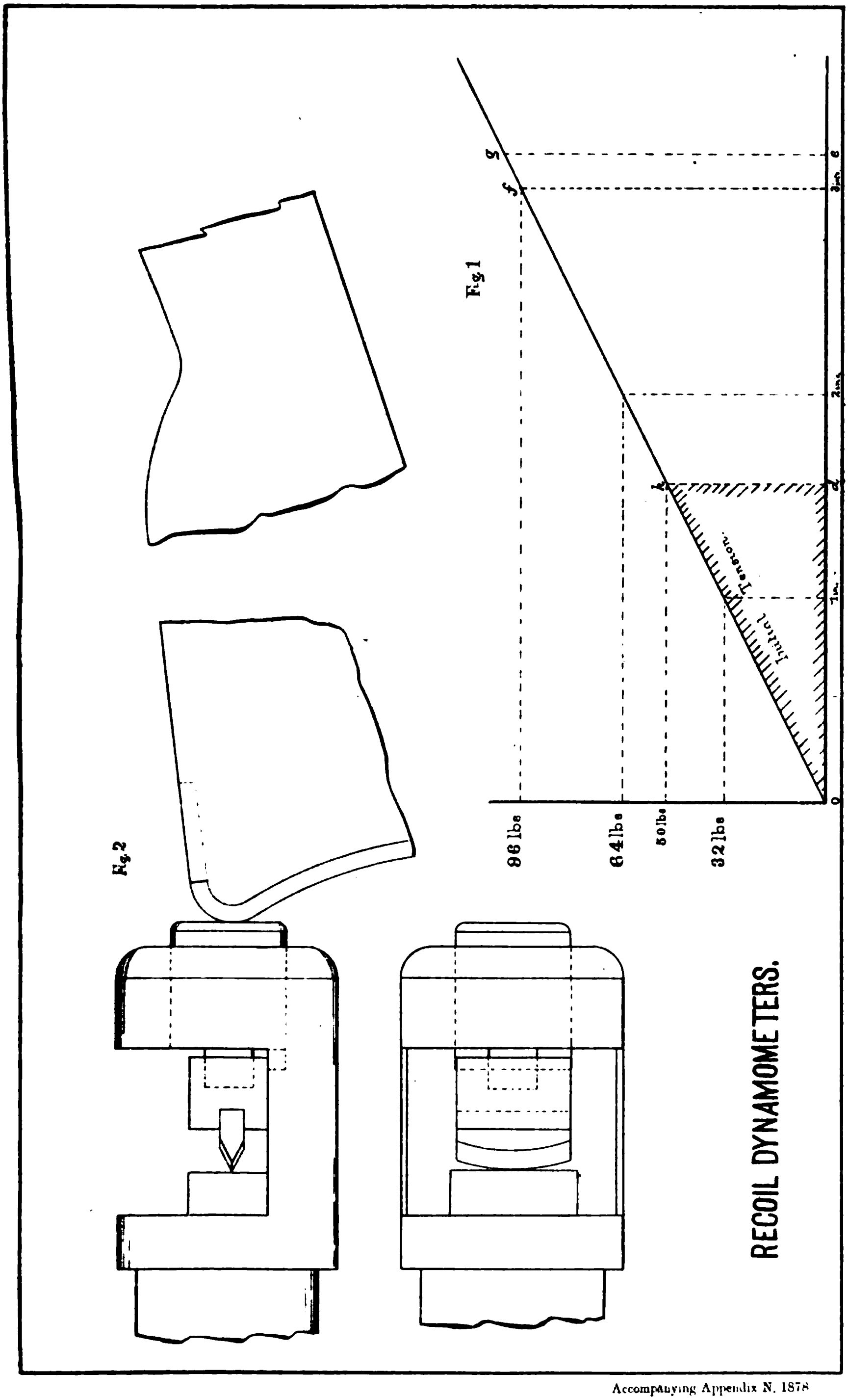
This difference is one observed in all similar comparisons, and is probably due to inertia developed in the particles of the spring and copper by the rapid application of the blow. The difference between the ratios can readily be accounted for on the score of errors of observation.

The foregoing paper was forwarded by the commanding officer of Frankford Arsenal to the Chief of Ordnance U. S. A., on May 22, 1878, with the following indorsement, viz:

"I have examined Lieutenant Metcalfe's report, which shows careful study, and believe his deductions to be correct. The spring in the recoil dynamometer should be compressed sufficiently by the recoil of the gun to admit of accurate measurement within prescribed limits, but not so much as to cause the butt of the gun to rise sensibly in its rearward motion. By making the recoil scale to represent *units of work* in its divisions rather than *statical pressures*, like causes will give equal numbers of units of work when the springs in the dynamometers vary in stiffness, the same unit for distances of compression being used in all cases; that is, C, in different instruments, always representing the weights required to compress the springs through the distance unity. I would respectfully recommend that the scales which register recoils on the recoil dynamometers be graduated according to units of work."

It was thereupon referred to Lieut. Col. J. G. Benton, commanding the National Armory, Springfield, Mass., who recommended that, as Lieutenant Metcalfe's views were evidently sound in theory, they be carried out in practice; and the Chief of Ordnance, under date of June 14, 1878, directed that in future all dynamometers will be graduated as recommended in the foregoing report.

S. C. LYFORD,
Major of Ordnance.


RECOIL DYNAMOMETERS.
Fig. 1
Fig. 2
96 lbs
64 lbs
50 lbs
32 lbs
Initial Tension
f
g
h
d
0

APPENDIX N 1.

TESTS OF LUBRICANTS FOR MACHINERY. BY FIRST LIEUT. HENRY METCALFE, ORDNANCE DEPARTMENT UNITED STATES ARMY.

(Two plates.)

FRANKFORD ARSENAL,
May 27, 1878.

A simple and efficient way of determining experimentally the co-efficient of friction on trunnions and axles has long been desired. While engaged at the National Armory, five years ago, in preparing rules for the inspection of lubricating oils, I devised the instrument shown in Fig. 1 as a convenient method of comparing the lubricating qualities of various oils.

The box A is filled to the level of the wire B with water at a temperature noted by the thermometer. A measured quantity of oil having been placed in the oil cup C, it passes down through its stem to the steel journal J. The bearing B is ground to fit closely the journal, generally connected with an emery grinder, belted ready for running at a high speed. The journal being set in motion with an approximately uniform velocity, the thermometer is watched until the temperature of the water in which the bulb is immersed has been raised any given number of degrees, say 20°. The time so required is taken as the measure of the lubricity of the oil.

The arrangement worked with fair accuracy, as will be seen from the table accompanying. The variation is ordinarily only about 5 per cent.

TABLE I.

Tests on new oil-testing machine.

The saddle was made of brass, 30 pounds pressure, on an area of 1.6642 square inches.

Weight of water at maximum density= 0.0955 pound.

Volume of water = 2.646 cubic inches.

Shaft, diameter 1″.06, running at 3,330 revolutions per minute.

Time required to raise water 20° F.

	Minutes.	Seconds.	Minutes.	Seconds.	Minutes.	Seconds.	Mean, seconds.	
Springfield sperm	2	20	2	17	2	20	139	
"C" oil	2	05	2	07	2	07	126	See Plate II.
Frankford mixture (½ "C," ½ sperm)*	1	55	1	58	1	55	116	
Shoemaker "true" sperm	1	55	......	......	......	......	115	
Frankford sperm*	1	50	1	50	1	43	107	
Frankford lard	1	50	1	45	1	40	105	
Springfield lard	1	40	1	45	1	40	102	
M oil, summer	1	40	1	42	1	30	97	
M oil, winter	1	35	1	40	1	35	96	
G oil, winter	1	35	1	32	1	38	95	
G oil, summer	1	20	1	22	1	15	79	See Plate II.

* This was afterward discovered to be whale oil.

These results, though roughly comparative, lost a great part of their value from their failure to account for the heat due to the work of friction which was dissipated by radiation and conduction; otherwise the work of the friction, and hence the co-efficient of friction, might be accurately deduced from the mechanical equivalent of the quantity of heat developed by it, as in Rumford's celebrated experiment.

The instrument was also evidently deficient in not taking into account the endurance of oils for long runs, nor the resistance due to their viscosity. In fact, each experiment was limited to a single observation.

Besides these objections, the oil to be tested could never be tried under the actual conditions of its use, but had to be tested on a bearing often far different from that which it was intended to lubricate.

The value of the co-efficient of friction may be deduced from the quantity of heat developed by the friction, by the following reasoning:

$$f = \frac{F}{W}, \text{ or } F = Wf;$$

multiplying both numbers by $s = 2 \pi R N$,

$$Fs = Wfs,$$

but $Fs = Q =$ work done by the friction, therefore

$$f = \frac{Q}{Ws}.$$

Taking the case of Springfield sperm oil, Table I, the heat due to the work of friction will, approximately speaking, raise in 139 seconds $\frac{1}{10}$ pound of water 20° F.

This is equivalent to raising 2 pounds 1°, or $Q = 2$ thermal units.

But 1 thermal unit = 772 foot-pounds, therefore $Q = 1{,}544$ foot-pounds, and—

$$f = \frac{Q}{W\, 2\, \pi\, R\, N}, \; N = 3330 \times \frac{139}{60};$$

or

$$f = \frac{1544}{30 \times \frac{1.06}{12} \times 3.14 \times 3330 \times 2.32} = 0.024.$$

This is surprisingly near the results by the other method. (See page 120.)

The different results obtained with the other oils are probably due to their different adaptability to the nature, size, and speed of the bearings.

A NEW METHOD OF DETERMINING AXLE FRICTION.

The following method then occurred to me for determining with exactness the co-efficient of friction. (See Fig. 2.) I selected an ordinary draw-press (see Ord. Mem. VIII), and having removed the clutch, ran the fly-wheel upon the eccentric shaft by a belt from the adjoining line of shafting, the bearing of the wheel upon the shaft being previously anointed with a measured quantity of oil, viz, 5 to 15 drops. After running any given time, the belt was thrown off in such a way as not to retard the wheel, and the wheel allowed to run down. Supposing the final impulse of the power to be constant, the best oil would yield the greatest number of turns before stopping and would run the longest time.

Such, roughly, is the principle of the machine. The details are developed by the following discussion:

A fly-wheel is set in rotation with an angular velocity $= \theta$.

The source of power is removed, and the wheel is allowed to run down until stopped by the resistance of the friction on its axle and that of the air.

The latter resistance is neglected in this discussion.

The living force of the wheel at the initial moment of the observation $= L = M K^2 \theta^2$; where $M =$ mass of the wheel and K is its radius of gyration. This is equal to twice the work of its inertia in stopping, consequently calling the work of its inertia $Q =$ we have—

$$Q = \frac{M K^2}{2} \theta^2. \qquad (1)$$

But the work of inertia of the wheel is overcome by the work of the force of friction (F), acting over a path $= 2 \pi R N$, in which R is the radius of the eye of the wheel and N the number of turns the wheel makes before stopping. The work of the friction, then, since it is a constant force, must be equal to its intensity F multiplied by its path, or

$$Q' = F\, 2 \pi R N;$$

but

$$Q = Q';$$

hence

$$F\, 2 \pi R N = \frac{M K^2}{2} \theta^2, \qquad (3)$$

and

$$F = \frac{M K^2 \theta^2}{4 \pi R N}. \qquad (4)$$

That the force of friction is a constant force has been determined, experimentally, to be true within widely varying velocities; consequently, as during the stopping of the wheel the only variable is the velocity, and its variation is not a great one, the rotation of the wheel in stopping may be considered as a case of uniformly retarded motion, the mean velocity of which, θ', is half the initial velocity θ, or

$$\theta' = \frac{\theta}{2}. \qquad (5)$$

Returning to equation (4), let t be the time in seconds of one turn at the rate at which the wheel is going at the moment of removal of the rotating power,

then $\theta = \frac{2 \pi}{t}$ $(R = 1)$; but from Eq. (5) $t = \frac{t'}{2}$, t' being the mean time of one turn in stopping, which is equal to $\frac{S}{N}$, S being the time in seconds required to stop.

So $t = \frac{S}{2 N}$ and $\theta = \frac{2 \pi}{\frac{S}{2 N}} = \frac{4 \pi N}{S}$; and $\theta^2 = \frac{16 \pi^2 N^2}{S^2}$.

Substituting in Eq. (4), viz:

$$F = \frac{M K^2}{4 \pi R N} \theta^2$$

$$F = \frac{4 M K^2 \pi}{R} \frac{N}{S^2}, \qquad (6)$$

But calling $f =$ the co-efficient of friction, or $f = \frac{F}{P}$, and allowing the weight alone of the wheel to act, we have—

$$f = \frac{F}{W}, \text{ or}$$

$$f = \frac{4 M K^2 \pi}{W R} \frac{N}{S^2}, \text{ but } M = \frac{W}{g},$$

consequently, under this supposition, the most natural one for practice with loose pulleys, by substituting the value of M,

$$f = \frac{4\,K^2\,\pi\,N}{R\,g\,S^2}. \qquad (7)$$

For any given wheel and place, K, π, R, and g are constant, hence the above may be written—

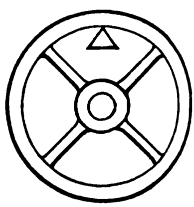
$$f = C\,\frac{N}{S^2}. \qquad (8)$$

If the wheel be driven at an approximately constant speed, we can obtain approximately accurate results by supposing the ratios of N to S to remain constant, since $t = \frac{S}{2N}$.

In this case equation (8) becomes

$$f = C'\,\frac{1}{S}\ (9),\ \text{or conversely}\ l = \frac{S}{C'},$$

C' being equal to $C\,\frac{\rho}{120}$, ρ being the rate in terms per minute at which the wheel is driven; or the lubricating value of an oil is directly in proportion to the time which the wheel will consume in running down after the power giving it rotation is removed; this power being constant for different trials and the wheel being only subject to the retarding force of friction.



K = the radius of gyration can be obtained by hanging the wheel as a compound pendulum giving N vibrations per hour.

$$K^2 = l\,e - e^2$$

$$l = \frac{l'\,(3600)^2}{N^2}$$

The following are the data for the wheel under trial:

		Log.
l' for Frankford Arsenal = 39″.0977 =		1.5921520
g for Frankford Arsenal = 385″.88 =		2.5864517
N = 72 beats per min. = 4320 per hour =		3.635484
e = 14″.3 = distance from center of wheel to point of support =		1.155336
W = 303 pounds.		
π =		0.497150
K =	13″.556	1.132137
K^2 =		2.264275
R = radius of eye of wheel	$\frac{2''.15}{2}$	0.031408

(length of axle-arm bearing = 5″.0)

from this a value for

$$C = 5.5670;\ \log.\ C = 0.745625.$$

A table is formed for different values of $\frac{D}{S^2}$ giving the logarithm of the quotient; entering this with the logarithm of the number of turns made before stopping, the logarithm of f is found by addition.

Keeping the wheel in constant motion except during the time consumed in taking observations at regular intervals—say of 5 hours—a

mean value for f can be found at each of the intervals and laid off as an ordinate from an axis of abscisses divided for hours.

The extremities of these ordinates being joined, a curve will be found showing the endurance of the oil at different times, and for equal times the lubricity of the oils may be compared inversely by the areas limited by their corresponding curves.

Example.

Oil.	Date.	Time.	Hours run.	Sec.	N.	f.
Whale (called "sperm")	March 22	11.30	24	70	29.5	0.03352
				69.5	29	0.03343
				66	29	0.03706
						.03467
Whale (called "sperm")	March 22	5.30	29	59	27	0.04319
				61	26.5	0.03965
				59	26.5	0.04239
						.04174

The following points require attention:

I. The results first obtained with a fixed axle were so high and irregular as to make me suspect their anomalies to be due to the denudation of the top of the axle by the revolution of the wheel, in this manner: Suppose the eye of the wheel to be practically larger than the axle; as the oil is swept from the line of contact, the upper element of the axle, it runs down the side and collects beneath the axle in a film of greater or lesser thickness. This does no service in lubrication unless it becomes heavy enough to drag against the eye of the wheel and be carried by it to the upper element of the axle.

Again, this line, or rather, from the compressibility of the materials of which the eye and axle are made, this *area* of contact becomes worn and highly polished in the course of 50 hours' run. In cleaning the axle for the next trial the same surface may or may not support the wheel, and thus cause a very material difference in the result. So to equalize matters, and to distribute the wear, I put a crossed belt on the head of the eccentric shaft, running it from the same line shaft at about 54 revolutions per minute in a direction contrary to that of the revolution of the wheel which ran at 53 revolutions.

The effect was immediately evident in the increase of the number of turns and of the time required to run down, although the relative velocity of the contiguous surfaces was doubled.

II. Although the wheel ran very uniformly at the rate of 53 turns per minute, yet during that minute the rate of rotation was always varying in consequence of the inability of the steam-engine's governor and fly-wheel to compensate instantaneously for drafts made on the source of power.

Hence the arrangement shown (equation 5), by which the impulse is not regarded as constant and differences in the initial velocity are allowed for.

The importance of this arrangement becomes apparent when it is considered that even when the co-efficient of friction is great a sufficiently forcible impulse may give as great a number of turns and may cause the wheel to turn as long a time as from a weaker impulse with less friction.

Experiment fully justifies the compensating power of the formula finally deduced. (See pp. 668, 669, and 670.)

III. The wheel was imperfectly balanced, so that its running was often unduly prolonged in point of time, in consequence of the passage of the heavy part by the center just as the motion was about to cease. The eye of the wheel contained several blow holes which served as oil pockets. The axle was rough in the beginning of the experiment. There was more or less lateral friction against the shoulder and washer.

With this arrangement the results recorded in the accompanying diagram were obtained; the mean of at least three trials being taken at each observation.

The influence of continued wear of the rubbing surfaces is plainly shown by the relative position of curves representing repeated trials of the same oil, as shown by the accompanying legend. The viscosity of the oils when first applied is shown by their comparatively high frictional values.

Good sperm oil after exhaustion of its fluidity would coat the bearing with a smooth sort of glaze, on which the running would continue without material change.

This was, however, a dangerous condition of affairs, for the slightest break in this film might have brought the naked metals in contact and have caused them to be galled or welded together.

To test the question of the independence of the formula (equation 8) from the force of the initial impulse, two sets of observations were made on the same oil—G—0 hours. First run by steam-power in the ordinary way at an average velocity of 53 turns, and then by hand with purposely very different initial impulses, as will be seen from the number of turns made before stopping.

The results were as follows:

	Sec.	N.	*f*.	
By power	125	48	0.01711	
	146	56.75	0.01482	
	142	58	0.01602	
			.01598	
By hand	106	30.4	0.01506	
	104	32.5	0.01673	
	87	20.4	0.01501	Light pull.
			.01560	

The absolute values of the co-efficients of friction thus obtained are much less than those recorded by Morin (see Bartlett, p. 503), or even by Prof. R. T. Thurston's lubricating testing machine (Polytechnic Review, March 3d, 1877). Here Professor Thurston gives, for the average of commercial oils, co-efficients varying with the pressure as follows:

Pressure per sq. inch.	Co-efficient of friction.
8	0.20
16	0.16
32	0.12
48	0.10

The absolute pressure per square inch must always be a hard matter to determine, especially in the case of a wheel, as it depends so largely upon the fitting of the surfaces. Judging by the mark left on the film of oil on removing the wheel used in my experiment from the axle, it

appeared to rest on a surface about $0''.6 \times 5''.0 = 3$ square inches. The weight of the wheel was 303 pounds, consequently the pressure was about 100 pounds per square inch.

This would partly account for the difference, part of which might also be due to differences in the bearing surfaces and in their relative velocity.

For these and other reasons the special testing machine shown, Fig. 3, was devised, and is now in construction.

It will be observed that the friction is that of a movable shaft on a fixed bearing, differing in this important particular from the device last described. The oil naturally gravitates to the point of greatest pressure; the wear of the bearing surfaces is compensated for; and, in a word, the circumstances resemble as closely as possible those of an ordinary bearing for line shafting, which, owing to its inaccessibility and the continuous motion there prevailing, is the most important for our consideration.

To apply as closely as may be to the conditions of practice at this arsenal, the shaft is made of wrought iron of the standard diameter $2\frac{3}{16}$ inches; the bearing is also that recommended by Sellers & Co. and Thurston, viz, of a length equal to four times the diameter of the shaft. The cap receives the pressure from the weighted lever above it, which can thus be increased to 100 pounds per square inch. There are no shoulders or washers to interfere with free rotation. A trough cast in the cap can be filled with water and used as in Fig. 1.

The two fly-wheels are to be carefully balanced. They will be driven by an independent clutch, shown on the side of the figure. Their revolutions will be counted by the following simple device: An ordinary Seth Thomas lever-clock is placed at right angles to the axis of the shaft and so near it that an eccentric pin on the end of the shaft will enter the side of the escapement. The clock being wound up will tend to beat and mark seconds, but by the action of the eccentric pin will be constrained from moving except so far as the revolutions of the shaft will permit; consequently each revolution of the shaft will be indicated as one half-second, and every 7,200 as one hour, and so on. The tension of the clock-spring relieves the shaft from the resistance of the clock-work.

If this should be found to work well, new gear-wheels will be introduced and an extended decimal notation provided for.

I propose to vary the composition of the boxes, using, besides cast iron, brass, Babbitt metal, &c.

For a practical illustration of the advantages of the formula above discussed, I recently applied it to the case of a gun-carriage wheel.

The value of $C = 9.512-$; (log. $= 0.978276$) was derived from the following data:

$N = 286$ in five minutes;
$e = 24''.66$;
l' at Frankford Arsenal $= 39.09777$ inches;
g " " " $= 32.15663$ feet;
$R =$ greatest diameter of eye $= 1.55$ inches;
in the formula

$$K^2 = \frac{\overline{l' 3600}^2}{N^2} \text{ sec. } e - e^2 \text{ and } C = \frac{4\pi K^2}{Rg}.$$

A carriage-body with a fairly smooth axle-arm was jacked up so as to make the upper element of the arm horizontal to the eye, or nearly so. The axle was successively lubricated with the following substances.

The impulses given to the wheel were as varied as was possible, as an inspection of the results will show.

The high velocities were obtained by pressing the end of a stick against the side of a spoke and keeping up the pressure as the wheel revolved by following the movement of the spoke.

As might have been expected the wheel was not balanced, nor was it possible to prevent occasional rubbing against the shoulder on the axle or the washer.

The axle also was purposely only leveled by the eye. These circumstances naturally affected disproportionately the results obtained with very low impulses, given, not so much to obtain apparently consistent results as to test in the most severe way possible the general truth of the theory. To my mind its truth is fully sustained. More consistent results might have been attained by a repetition, from which I have purposely refrained.

Springfield sperm-oil freely applied.

	N.	Sec.	*f.*
1	19.5	45	0.09160
2	20.5	47	0.08827
3	21.25	55	0.06682
4	4.3	23	0.07732
5	2.7	15	0.11410
6	28.3	59	0.07733
			0.08590

Castor-oil freely applied.

	N.	Sec.	*f.*
1	49.6	125	0.03019
2	40.5	117	0.02814
3	19.5	67	0.04132 turned backward.
4	9.6	545	0.03074
5	65.5	158	0.02496
6	119.	200	0.02782
			0.02837

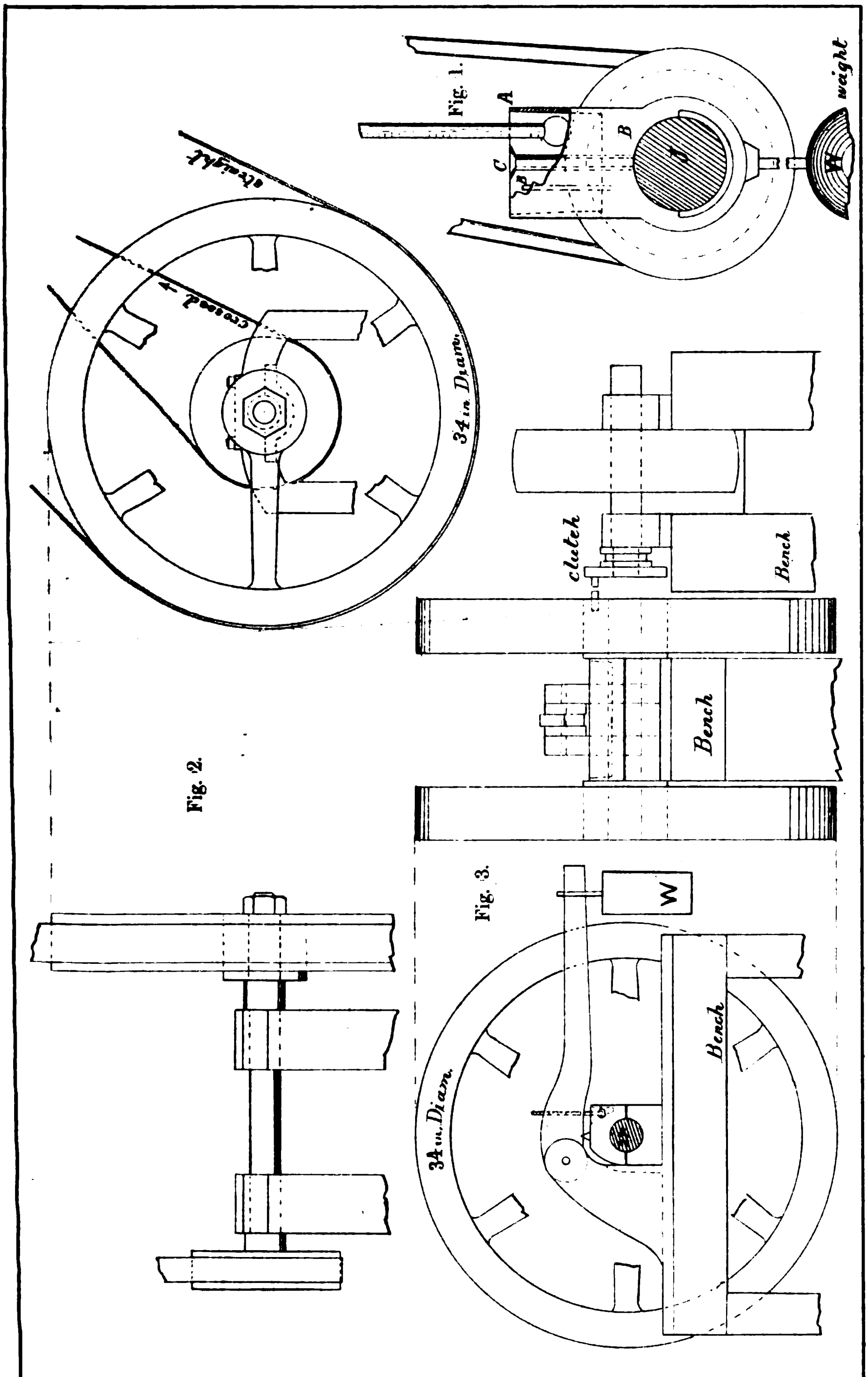
Axle-grease. Composed of tar, tallow, and plumbago.

	N.	Sec.	*f.*
1	98.6	175	0.03062
2	36.75	169	0.01224
3	12.5	62	0.03093
4	2.8	25.5	0.04096
5	63.75	154	0.02557
			.02806 or .03202

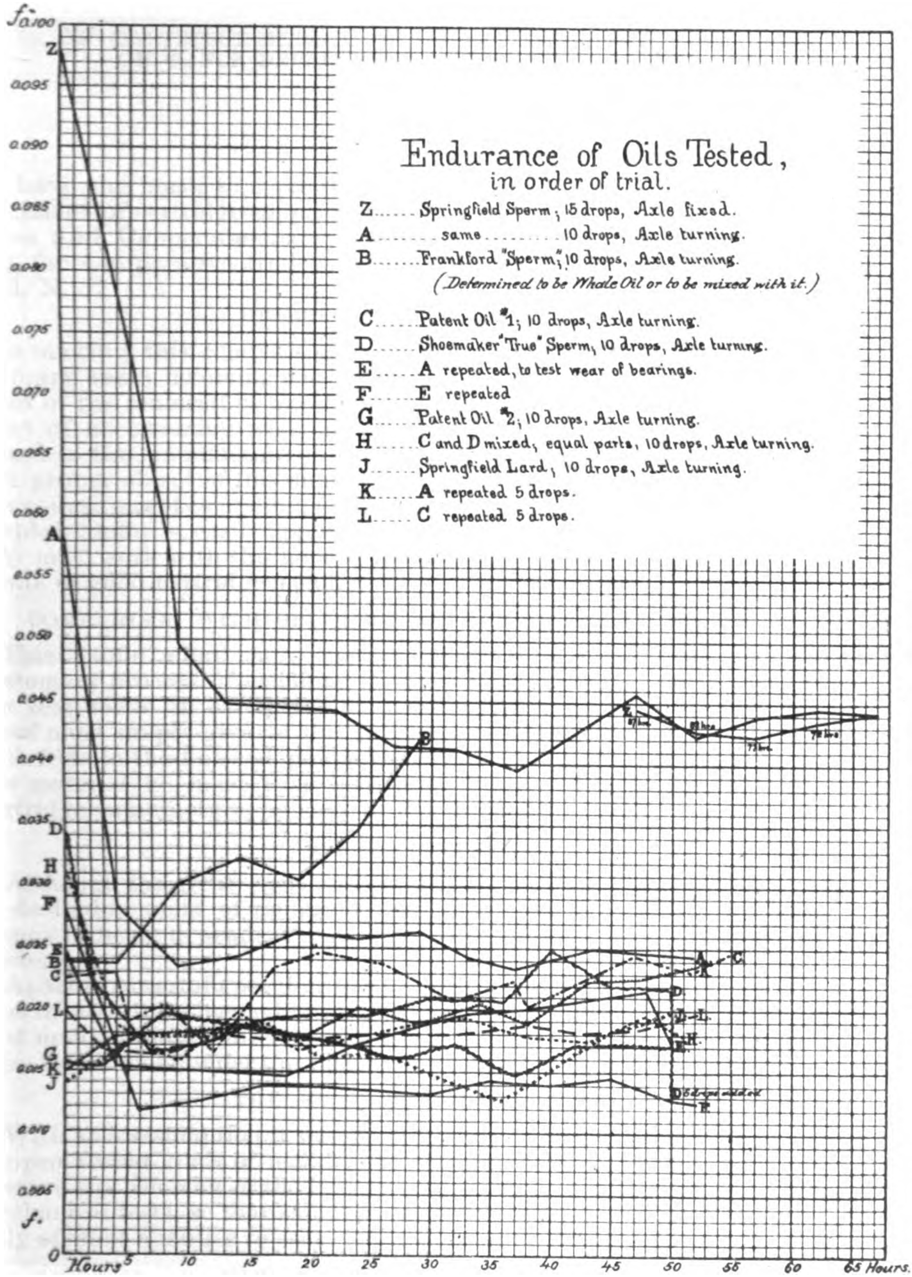
The application of this to experimental comparisons of axle-grease is evident.

Apply each lubricant to one axle of the vehicle; travel with it any given number of miles, then obtain the corresponding values of *f*. If the bearings differ in smoothness, alternate the lubricants.

If this theory should prove well founded, I would advise that the new edition of the Ordnance Manual contain values of C for all wheels used on ordnance field-carriages.



Accompanying Appendix No. 1878



Accompanying Appendix N[1], 1878

APPENDIX N 2.

TESTS OF CARTRIDGE-METALS. BY FIRST LIEUT. HENRY METCALFE, ORDNANCE DEPARTMENT, UNITED STATES ARMY.

(Eight plates.)

FRANKFORD ARSENAL,
January 22, 1878.

I have the honor to make the following report upon the test of certain specimens of cartridge-copper or gilding metal submitted by the Ansonia Brass and Copper Company, and by Messrs. Merchant & Co. of this city, for comparative trial with copper made Mr. J. G. Moffet, Bloomfield, N. J.

OBJECT OF INVESTIGATION.

In making this comparison I was induced, not only to carry out the ordinary tests involving facility of manufacture and endurance under proof of the material in question, but also to extend my inquiries to the point of ascertaining what are the physical peculiarities of metal best suited to the manufacture of metallic ammunition.

A proper object of this inquiry I conceive to be, to furnish manufacturers desirous of competing for the supply of cartridge-metal with certain simple standards, easily applied in their own workshops, and up to which they may work with the hope of immediately approaching the requirements of good cartridge-metal.

COMPARISON WITH ORDINARY METHOD OF TESTING COPPER.

This should afford more encouragement to manufacturers than the customary process of confining the inquiry to making up a quantity of the test metal in cartridges for powder-proof; for the results of this proof must simply give to the manufacturer knowledge of advantages or defects in the finished product, concerning the cause of which in the raw material he must, from lack of familiarity with the operations of cartridge manufacture, be more or less in doubt.

MOFFET COPPER.

Although the great excellence of Mr. Moffet's copper leaves little to be desired in point of uniformity and useful strength, still the inexpediency of being dependent upon but one mill for our supply of copper is evident.

Apart from certain peculiarities evident in manufacture, such as seaminess of structure, inequality in thickness, &c., I hope it may be found that many of the requirements of good cartridge-metal may be deduced from its behavior under the various mechanical tests hereafter described.

THEORY OF INVESTIGATION.

With this assumption it was determined first to ascertain by the powder-proof what kinds of metal gave the best practical results; then to observe the behavior of the best and worst of these materials under the mechanical tests, so that safe inferences might be thereafter drawn, not only of what qualities to seek, but also of what defects to avoid.

VARIETY OF METALS TESTED.

Then, also, other materials of as diverse characters as possible, such as brass annealed and not annealed, pure copper, and even soft Bessemer steel, were admitted into the lists, with the hope that the extent of the

field covered by their diversities would permit a more general, and therefore a more truthful, view to be taken of their requirements than if the scope of the inquiry were limited to the slight differences between metals, which, in their approach to a common standard, already resemble each other, as far as the skill of their makers would allow.

THE POWDER PROOF.

Éprouvette.

For this purpose the Gill éprouvette, shown Plate I, Fig. 1, was employed. Its operation is very simple: The charge of powder is gradually increased until the pressure developed by the inertia of the constant weight is just sufficient to cause the cartridge to yield. The cartridge is held in a chamber which is the exact counterpart of that of the Springfield gun. The least weight of rifle-powder in grains, causing rupture, is taken as the effective value of the cartridge. (For particulars, see Plate XXIV, Ordnance Memoranda, No. 14.)

Comparison with tests made in rifle.

Experiments which I have made in connection with this report lead me to greatly prefer the éprouvette to the use of a gun for the extreme proof of cartridge-cases.

In firing in a gun with the high charges necessary to destroy the case, an enlargement of the cartridge-head space necessarily follows from the setting back of the breech-block upon its bearings. So that in using the same gun for the extreme proof of different cartridges the conditions may change with each discharge.

This is particularly the case with cartridges which fail from shearing, as will be explained further on.

Yielding of system under heavy strain.

It will be sufficient to cite the example of certain cartridges which stood on one occasion 81 grains of English rifle-powder and one service-bullet. When the trial was repeated next day they could only be made to stand 77 grains and one bullet.

Advantages of éprouvette.

The advantage of the éprouvette undoubtedly consists in this: that by excluding all variations in the firmness of the closure and the condition of the bore, it limits the inquiry most strictly to the single variable under consideration.

The results were as follows:

TABLE I.—*Results of firing in éprouvette.*

	Ansonia.		Brass.		Merchant.		Moffet.		Pure copper.	Steel.	
	XII.	XV.	Not annealed.	Annealed.	Not annealed.	Annealed.	Not annealed.	Annealed.		.028 thick.	.030 thick.
	Grs.	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*
Burst in flange	24	22	24	......	......	......	......	......	18	<10	17
Head sheared	......	......	......	25+	26	25	23	23	......	......	......

The lowest limit of the thin steel was not reached, as the escape of gas, even with such low charges as 10 grains, was such as to tend to

injure the éprouvette by scoring. The brass not annealed gave way badly, in one case a piece being blown or melted from the rim.

These conclusions as to the comparative strength of the Merchant and Moffet coppers were subsequently verified by firing 10 of each with 24-grain charges in the éprouvette; 4 of the Merchant and 8 of the Moffet failed by shearing.

DISTINCTION BETWEEN SHEARING AND BURSTING.

Sheared heads.

The character of the rupture demands attention. It will be observed that the Moffet and Merchant metals always parted by shearing. This is a specific term used to denote the parting of the metal on the line of *a b*, Plate I, Fig. 2, due to the pressure of the gas on the ring *c d*, and to the rigid resistance of the edge of the chamber at *e*. This defect is common to all folded head cartridges, in none of which necessarily can this ring be less in depth than the thickness of the metal of which the head is made. Its maximum depth is limited by the backward movement of the breech-block under the pressure of the gases in firing, thereby virtually enlarging the cartridge-head space.

By thickening the head, as in some solid-head cartridges, so that its inner surface may come within the line *a b*, this strain may be obviated.

Burst heads.

The brass, steel, and Ansonia cartridges, on the other hand, appeared to part principally in the circle represented in section by the point *f*. This seems the line of separation between that portion of the head most severely squeezed and hardened by the operation of heading, viz, the area inside of *f*, and the more extensible, because more unsupported, narrow ring outside of it. The structural change ("demoralization") due to this variation in pressure is probably heightened by the influence at that point of the cold-shut bend of the flange.

This effect was plainly seen even in cartridges where absolute rupture did not occur. The circular area inside of *f* seemed to have been stretched bodily, like a drum-head, away from the original plane of the head to a position, say *g g*. From this position, when it did not break, its elasticity generally brought it back, leaving a shallow annular groove at *f*. The cases also sometimes broke in the fold, as at *h*. This was particularly the case with the steel.

The results of this powder proof would lead one to characterize the greater part of the metals, except Merchant's, as hard, short, and unyielding in comparison with the Moffet copper.

MECHANICAL TESTS.

These were for tensile strength with progressive elongations under strain; applied, 1st, statically; 2d, dynamically; 3d, resistance to shearing by shock; 4th, structural effect of close bending under pressure.

I.—TENSILE STRAIN.

Form of specimens.

The standard specimens were in every case after No. 24 Laboratory Record of the form shown, Plate III, Fig. 1, and cut lengthwise of the

strip. The line of least resistance was sometimes shortened where great resistance was expected. The points *a b* were laid off half an inch on each side of the line of least resistance, and the elongation between them measured at each increment of strain. This short length, one inch, was taken as the basis for such measurements, in order to compare with the necessarily local nature of powder-strains upon the cartridge-case in service. A number of observations on metals of different kinds fixed the total elongation of the specimen at about 0''.1 more than the total elongation of the middle inch, whether that elongation was 0.''265, 0''.29, or 0''.32. I have consequently neglected the elongation of that portion of the specimen outside of the points *a b*, although it undoubtedly increases the apparent resistance of the middle inch, on the ground that the equality of the results above indicated, despite the unequal ductility of the materials undergoing strain, must indicate that the free extension of the part in question is so greatly affected by the friction of the clamps as to render its comparative indications of no value.

I therefore consider that truly relative results in this case may be obtained by confining our attention to that portion of the specimen in the immediate vicinity of the fracture, provided that the specimens are originally of the same form and dimensions.

This subject is well treated in a paper by Mr. C. B. Richards, of Colt's Armory, read before the American Society of Civil Engineers, January 21, 1874. Mr. Richards's conclusions, although at first sight opposed to those above enunciated, will, I think, be found to confirm them on examination.

The ends of the specimens are bent over to fit in narrow grooves cut in one of the interior surfaces of each of the clamps. This precaution was adopted after the proof of specimen No. 24, on account of the apparent slipping of the specimens in the clamps when held by friction alone, as shown by the curving inward of the ends in former trials.

* * * * * * *

Testing machine.

To procure the tensile strain a testing machine was extemporized as follows:

The specimen is firmly held in clamps, the stem of the upper one of which is extended to form a vertical screw above it. The lower clamp is also extended to form a stirrup, a knife-edge on the sole of which supports one end of a heavy iron beam. The other end rests on a knife-edge on the platform of a Fairbanks scale. This beam is held down at midlength by a bolt, the lower end of which is fastened to a lug cast on the frame of an old punching press, which serves as the general frame of the machine. The eye in this bolt is square, and its under side is formed into a knife-edge resting on the upper side of the beam.

The vertical straining screw passes through an old casting bolted on the top of the frame, and works on a feather to prevent rotation in rising. The frame is kept from rising bodily under the influence of the strain, by a prop wedged in tightly against an iron floor-beam above it.

The platform frame of the scale is supported on a wooden block resting on the floor, high enough to take all strain off the journals of the truck-wheels.

The strain was brought to bear by means of the cross-handled nut shown in the sketch, the elongation between *a* and *b* being followed up meanwhile by an assistant with a pair of spring dividers.

When the weight upon the scale beam was raised, the dividers were

removed and the space measured. It was thus possible to follow up the stretch until the metal could actually be seen begining to part, when the dividers were removed.

That these arrangements, though rude, gave very consistent results, will, I think, appear from an examination of Table II. Much of this accuracy is due to the care and skill displayed by Mr. McBride, of the machine shop of this arsenal, who assisted me throughout these experiments.

Arranging the testing machine cost about $20.

TABLE II.

Maximum differences in elongation under static tensile strain with improvised testing machine.

Material.	Ansonia.		Brass.		Merchant.		Moffet.	Pure copper.	Steel.
	XII.	XV.	Not annealed.	Annealed.	Not annealed.	Annealed.			
Number of specimens.	3	3	1	3	4	4	3	4	*3
Pounds.									
300	....	....	....	....	....	....	....	0''.000	
400	....	....	....	....	....	....	....	.015	
500	....	....	....	....	0''.000	0''.005	0''.000	.010	
600	....	....	....	....	.000	.010	.000	.010	
700	....	0''.000	....	....	.005	.015	.005	.005	
800	0''.005	.005	....	....	.015	.015	.005	.010	
900	.000	.005	....	0''.000	.015	.010	.005	.045	
1000	.000	.005	....	.005	.005	.010	.005	.005	
1100	.000	.010	....	.000	.005	.015	.01	(†) ?	0''.005
1200	.005	.000	....	.005	.035	.015	....	....	.005
1300	.005	.005	....	.010	.015	.020	....	....	.015
1400	.005	.000	....	.010	....	....	....	....	.010
1500	....	....	....	.005	....	....	....	....	.015
1600	....	....	....	.010	....	....	....	....	.055
1700	....	....	....	.015	....	....	....	....	
1800	....	....	....	.005	....	....	....	....	
Variation...	0.0009	0.0012	....	0.0022	0.0026	0.0032	0.0014	0.0031	0.0058

*From different strips. †One specimen only stretched to .225. See Abstract of Tests.

The figures expressing variation are obtained by dividing the sum of the maximum differences by the number of observations.

Comparative uniformity.

The Moffet and the two Ansonia coppers are the most uniform. The steel, pure copper, and Merchant's annealed are the least uniform. Brass and Merchant's, not annealed, are about a mean between the other two.

Curves of elongations under tensile strain.

The mean results are plotted in the accompanying curves, Plates IV—VIII, in which the divisions of the axis of abscisses represent the elongations in hundredths of an inch, due to hundred-pound strains, indicated along the axis of ordinates.

Each square thus represents 100 pounds × 0''. 01 = 1 inch-pound.

Effect of variations in thickness.

Differences in section, due to variation in the thickness of the metal, have been neglected where this variation was slight. Numbers of ex-

periments show generally that the indicated resistances for small sections are proportionately greater than for large sections. (See Plate VIII.) Sometimes even a slightly higher section resists absolutely less than a low section, e.g., 1′ × 0″.031 less than 1′ × 0″.030. Accidental differences apart, this is probably due to the greater condensation due to rolling down the thin metal.

By supposing the skin so formed to be of an absolute thickness the greater proportionate strength of thin metal might be accounted for. (See Appendix.)

These differences exist mainly in the elongations due to progressive strains. The breaking strains are nearly always proportional to the sectional area. The form of the specimen also affects its elongation. (See Appendix.)

The curves are plotted for each kind of material separately.

Each sheet also contains, as a common standard, the Moffet curve.

All the curves are combined for comparison. Plate VII.

II. TENSILE STRENGTH AGAINST SHOCK.

Object of experiment.

It was at one time thought that valuable data might be derived from rupturing the specimens under the shock of a falling weight, which might be supposed to resemble in its effect the sudden explosion of gun-powder. The arrangement shown, Plate III, Fig. 3, was devised for this purpose.

Apparatus.

A weight was made to slide freely on a $\frac{7}{8}$-inch iron rod graduated in feet and tenths of a foot, and suspended from the eye of the lower clamp used in the testing machine. The other clamp was attached to the web of an iron floor-beam, the specimen being held between the two clamps, as previously described.

By successive trials a point was found from which one blow of the falling weight was just sufficient to produce rupture. The mechanical effect of this blow was assumed as the value of the material against shock. (See Table III.)

This rod was about 6 feet long and weighed, with the lower clamp, 21.5 pounds, enough to stretch the specimen fairly so as to avoid local tearing strains, and yet not enough to contribute specifically by its own weight to its yielding. It was made heavy, also, so as to avoid as far as possible its own extension by the blow.

Necessity for an invariable weight.

To obtain comparative results, however, it was found necessary that the falling weight should not be changed. For it was found by increasing the weight from 16.5 pounds to 22 pounds = 33 per cent., that not only was the necessary height of fall proportionately diminished, but that the total foot-pounds of the blow could be further diminished 15 per cent. without failing to produce rupture.

Effect of changing weight.

This result was arrived at accidentally, in consequence of the rod being found too short to allow rupture of the brass specimens to result

from the falling of the 16.5-pound weight, which the experiments were begun. The value for brass subjected this strain is thus deduced from this supposition, and is given as if for eight of 16.5 pounds.

This subject has been recently adverted by Professor Kick, of Prague. (See Van Nostrand's Magazine, vol. VII, page 268, September, 1877.)

Ratio between resistance under shock and slow strain.

Experiments made at this arsenal indicate a ratio from about 2.8 for the high metals to 3.4 for the more ductile ones, between the resistance due to shock with a falling weight of 16.5 pounds and that due to slow tensile strain. Contrary to my expectations, in no case was the shock resistance less than the other. (See Table VI.)

The rupture of the material was generally in the case of shock, as in the case of slow strain, determined by the elongation. For the same metal the total elongations in both cases were approximately equal, and so were the areas of rupture.

Comparative unimportance of this test.

The close parallelism existing between the results derived from this test and those obtained from the tensile strain, together with the advantages which the latter method affords of watching the behavior of the metal while "on the rack," not to speak of the necessarily tentative process required in determining this form of resistance, led me to attach but a secondary importance to its results and to prefer more than ever the indications given by the slow tensile strain.

TABLE III.

Resistance to falling weight or 16.5 pounds.

	Ansonia. XII.	Ansonia. XV.	Brass.	Merchant.	Moffet.	Pure copper.	Steel .026 thick.
Resistance in foot-pounds of blow	76.1	76 (?)	<115	79 (?)	80.0	53.6	55.0
Area of fracture reduced to per cent	70	64 (?)	60	64	77	73	69

III. SHEARING TEST.

Object.

It was thought that the tendency of the metal to shear, as described on page 672, might be predicated from its behavior under a punching press. This arrangement shown in Fig. 2, Plate III, was accordingly devised for this purpose.

Apparatus.

It consists of a cylindrical housing of cast iron, bored through and bushed for a half-inch punch and die. The sliding weight of 3 pounds is let fall from increasing heights upon the punch until its energy is just sufficient to drive the punch through the metal. This energy, expressed

in foot-pounds, is then taken as the shearing value of the metal. The diameter of punch = 0″.5 was selected on account of its close approximation to the diameter of the cartridge at the shearing point, viz, under the head.

In order to make the results as closely comparable as possible, care was taken that the punch and the die should always be sharp. Weights of 7 and 9 pounds were also used, with consistent results.

Slow hydraulic pressure.

It was at first attempted to compare these resistances under the circumstances of hydraulic pressure, but the rate at which the pressure was applied exercised so important an influence upon the result that this course was abandoned and was replaced by the method of an invariable blow. The actual pressure necessary to punch the Moffet copper was found to be about 1,600 pounds under the hydraulic press.

General discussion of results.

These resistances give some idea of the value of the metal against the shearing strains of the explosion, provided that it is not so weak from other causes as to burst in the head or flange before its full resistance to shearing can be developed. For example, brass has a high shearing value, but its bending value (see Art. IV) is so low as to cause it to burst and the gas pressure to be reduced before the full shearing resistance can come into play. By preventing this bursting by means of an interior gas-check the great strength of the material may be fully developed.

TABLE IV.

Resistance to shearing.

	Ansonia copper.				Brass.		Merchant.		Moffet.		Pure copper.		Steel.	
	XII.		XV.											
	Not annealed.	Annealed.	Not annealed.	Annealed.	Not annealed.	Annealed.	Not annealed.	Annealed.	Not annealed.	Annealed.	Not annealed.	Annealed.	.026 thick.	.030 thick.
Effect of minimum blow in foot-pounds.	4.45	4.31	4.52	4.31	4.94	4.87	4.17	4.17	4.06	3.81	3.60	3.66	5.31	7.5

IV. BENDING.

Object of test—Operation.

In order to approximate to the structural change due to close bending under pressure in the heading machine, strips of the metals were cut 0″.25 wide, and about 2″ long, and having been doubled over, were squeezed to a tight fold under hydraulic pressure. To do this required about 1,200 pounds pressure, applied over an area 0″.25 by 0″.75. The closely-folded specimens were then removed and opened slowly by hand. A certain point was generally found at which the metal was felt to give way sud-

denly with a kind of crack, showing that the useful resistance of the metal was overcome. The opening might be continued a little further without absolute separation taking place, but nevertheless it could be plainly felt when the life of the metal was gone.

The angles of opening at which the yielding occurred are shown. (Table V.)

That of thin steel was difficult to obtain exactly owing to the difficulty of starting the angle from the inside edge of the fold. There was an almost irresistible tendency to open around a secondary line about 0″.1 above the fold. (See Test Record.)

The apparent strength due to this peculiarity must account for the discrepancy between the results given in Table V for the different thicknesses of steel.

TABLE V.

	Ansonia.		Brass.		Merchant.	Moffet.	Pure copper.	Steel.	
	XII.	XV.							
	Not annealed.	Not annealed.	Not annealed.	Annealed.	Annealed.	Not annealed.	Not annealed.	.028 thick.	.030 thick.
Angle of opening	87	165	42	40	285	360	27	264° (?)	30°

General value of bending test.

With this exception and that of annealed brass, elsewhere noted, it will be found that the bursting of cartridges in the fold can generally be expected where a low angle of opening is found. See the case of pure copper, which, owing to its proverbial stringiness, was fully expected to have a high value under this test, but which, when fired, burst badly. So that with this test to weed out materials liable to burst, and the test for tensile strength to compare those liable to shear, it would seem that definite expectations might be reached before a single cartridge should be made.

* * * * * * *

DISCUSSION OF THE STATICAL TENSILE TEST AS TO ULTIMATE STRENGTH.

To return to the results of the tensile strain. (Plate VII.)

These results, regarding either extreme resistance or extreme ductility, exhibit at once a striking want of harmony with the indications of the éprouvette. The (statically) strongest of all, the brass, bursts with nearly the same charge required to shear the Moffet copper, the weakest of all in ultimate strength; and brass which is (statically) weakened by annealing, absolutely gains in powder strength by the change. (Compare also steel and copper.)

The Merchant metal is of the same or greater powder strength than the annealed brass, which, however, far exceeds it in statical strength *and ductility.*

As to ductility.

The range in ductility when under the same strain is very great. For example, the Martin steel will stretch under a weight of 1,100 pounds,

the lowest strain giving it a measurable extension, about $\frac{1}{60}$ as much as the Moffet copper under the same strain. Nearly the same relation exists in the case of brass.

Similar results are obtained by drawing the line of comparison parallel to the axis of ordinates. The Moffet copper stretches as much at 900 pounds as the brass does at 1,450 or the steel at 1,550.

Combination of strength and ductility for comparison.

It appears, therefore, that for the effective comparison of these materials we should consider their corresponding resistances and elongation *together*, by regarding the areas included between the curves and the axis in the direction of which the elongations are produced, viz, the axis of abscisses.

Areas of curves.

These areas are called by General Rodman (see Experiments on Metals for Cannon and Cannon Powder, page 171) expressions for the capacity for work of the specimens in question, in that they represent the work done by the specimen in resisting the breaking force. By other writers since General Rodman, Thurston and others, they are called expressions for the *resiliency* of the specimens, resiliency being a quality compounded of tensile strength and ductility; for example, of two beams undergoing transverse strain, that is the most resilient which will bend most under the greatest load without breaking.

Unimportance of considering ultimate resilience.

It is evident, from the flattening of some of these curves in their terminal portion, that after a certain strain but slight real resistance is encountered, and that the prolongation of the curve is merely due to the final slipping of the particles over each other before letting go. But this extension of the curve, in consequence of its being so nearly parallel to the axis of abscisses, adds disproportionately to its apparent strength, as indicated by the area of resilience.

Resilience within elastic limit.

So that in engineering practice, for materials to be used in construction, the most important resilience is held to be that taken at the elastic limit of the material.

Another reason for not regarding the total area of resilience of the metals is to be found in the fact that, notwithstanding the great difference in their conduct under strain, with four exceptions these areas are approximately equal. (See Table VI.) These exceptions are found in the two specimens of brass, in the pure copper, and in one specimen of steel.

Determination of limit for area of resilience.

The apparatus at my command did not permit so nice a point to be determined, and I was therefore induced to find a horizontal of comparison by reasoning based upon the indications of the Rodman pressure-gauge in the firing of service and destructive charges.

For example, supposing the cartridge case to yield by shearing, as explained on page 672, let us seek to determine the pressure causing this change of form.

Whatever may be the nature of the powder force, either static or dynamic, its effects are clearly interpreted by us *statically;* and the lever press used with the Rodman gauge may be the same dynamometer employed to determine the tensile resistance of the material. This gives a common measure for the resistance of the metal under such widely different strains.

The distance $c\ d$, Plate I, Figure 2, in a standard cartridge measures $0''.037 = l$. Supposing the cartridge to be so firmly supported from the rear that this space cannot be increased by the recoil of the cartridge under the influence of explosion, the shearing of the cartridge will be due to the radial pressure of the gas upon the interior surface of a cylinder whose diameter is that of the cartridge at d, and whose height$=c\ d=l$.

The effect of this pressure is to bend the walls outward around the line shown at e, as an axis.

Considering an elementary portion of the interior surface of the cylinder, calling the gas pressure P, and supposing it to act uniformly on the surface, it may be supposed to be concentrated at its middle point; hence its moment will be equal to

$$P \times \frac{1}{2}\, l = \frac{Pl}{2}.$$

The expansion due to this pressure will be resisted by the edge of the counterbore at e. Calling this resistance Q, its moment will be Ql, and equating moments

$$\frac{Pl}{2} = Ql, \text{ or } \frac{P}{2} = Q.$$

The shearing point will also be determined by the thickness $d\ e$; by the form of the edge; and probably by other circumstances affecting the combustion of the charge.

By determining experimentally, by means of the Rodman pressure-gauge and dynamometer, a statical measure of the lowest pressure required to effect this shearing, we may compare the extreme strains under which rupture takes place both in the gun and in the testing machine, and so obtain a co-efficient expressing the greater or less resistance of the material under powder pressure.

Statical value of service charge.

By then applying this co-efficient to the pressure obtained with the service charge, we may determine a certain tensile strain, under which the behavior of various cartridge metals may be discussed as if under the actual conditions of service.

In practice the foregoing assumptions are modified as follows: the distance $c\ d$ is never $= 0''.037$, but, owing to the depth of the counterbore and to the setting back of the breech-block under the influence of the discharge, is always greater than $0''.037$. In the gun used here for proving ammunition it is $0''.075 - 0''.03 = 0''.405$.

In the testing machine the resistance is predicated on a specimen with a section $1''.0 \times 0''.03$. To obtain the corresponding pressure in the gun, that is, the shearing pressure along one inch of the edge of the counter bore, we must multiply the pressure per square inch at d by the length $e\ d = l$; and to reduce this to the condition of thickness of metal existing in the case of the machine tensile strain the product must be increased one-fifth, as the metal at the shearing point is only $0''.025$ thick. Con-

sequently, the statical value of any shearing powder strain may be deduced from the formula:

Formula for statical value of shearing powder strain.

$$S = \frac{6Pl}{5 \times 2} = \frac{3Pl}{5},$$

in which P is the indicated pressure per square inch of the fired charge, and l is the length in inches of the cylindrical space above referred to.

Ultimate resistance in gun.

To determine the ultimate resistance of the service case, I fired two cartridges loaded with 88 grains of English rifle powder and one ball, from the rifle used here in proving ammunition.

The rifle measured, before firing, 0''.075 between the face of the breech-block and the bottom of the counter-bore. Two cartridges of Moffet copper, loaded with 88 grains of rifle powder and one bullet of 405 grains, were fired in it; one cartridge stood and one sheared; showing, if no change had occurred in the counter-bore space in consequence of the firing of the first cartridge, that this was the lowest charge developing the ultimate strength of the case, within the limit of the material's variation.

The counter-bore space was measured after the firing, and found apparently unchanged.

Compression of parts of system.

The cartridge which stood the charge was measured from the impression left by the edge of the counter-bore to the highest point of the head. This distance was found to be 0''.087, showing a compression under the strain of the explosion of the parts of the breech mechanism = 0''.087 − 0''.075 = 0''.012.

Effect on gun.

This compression was sufficient to raise the hammer to the half-cock notch by the lifting of the firing-pin guard. The cam-latch stood at about 30° toward opening.

The area operated upon by the gas pressure to produce shearing is determined by l = 0''.087 − 0''.03 = 0''.057.

P was determined experimentally by the Rodman pressure-gauge at about 37,500 pounds. The cut exceeded slightly the limits of the dynamometer.

(NOTE.—In this experiment the counter-bore space being invariably = 0''.070, from the character of the fixture in which the pressure housing was held, there was no sign of rupture of the metal.)

Consequently, $S = \frac{3}{5}(37{,}500 \times 0.057) = 1{,}282.5$ pounds, very nearly the ultimate strength of the material as found from the testing machine, viz, 1,100 pounds. Hence the co-efficient of comparison may be taken = 1. This accordance goes far to substantiate the theory of the Rodman pressure-gauge.

The difference of 182.5 pounds may easily be attributed to the tangential strength of the cylinder, to inaccuracies of measurement, and to the circumstances detailed above.

Application to service charge—Abscissa of comparison at 700 pounds.

In practice with the service charge the gun sets back to, say, 0″.075' then $l = .045$. The pressure 25,000 pounds, and $S = 675$ pounds; this gives us then a fair co-ordinate of comparison for the conditions of practice. Calling it, for safety, in round numbers 700 pounds, we obtain the areas of resilience given in Table VI under the head of inch-pounds resilience up to 700 pounds strain. These are convenient numerical expressions for the continuous ductility of the metals under consideration, up to the critical 700 pounds strain.

TABLE VI.

	Ansonia copper.				Brass.		Merchant.		Moffett.		Pure copper.		Steel.	
	XII.		XV.											
	Not annealed.	Annealed.	Not annealed.	Annealed.	Not annealed.	Annealed.	Not annealed.	Annealed.	Not annealed.	Annealed.	Not annealed.	Annealed.	.026 thick.	.030 thick.
Éprouvette failed at, grains. { sheared	......	....	......	....	......	25+	26	25	23	23	......	....	......	......
Éprouvette failed at, grains. { burst.	24	....	22	....	24	......	......	......	......	....	18	....	<10	17
Breaking tensile strain, pounds.	1400	....	1400	....	1800	1650	1300	1300	1100	....	1000	....	†800	1600
Total elongation	.0226	....	0.27	....	0.322	0.39	0.29	0.295	0.296	....	0.155	....	.0167	0.126
Area of fracture, %..	70	....	70	....	67	63	65	65	63	....	77	....	82	75
Variation	.0009	....	.0012	....	.0022	......	.0026	.0032	.0014	....	.0031	....	......	.0058
Ultimate resilience, foot-pounds.	26.4	....	26.7	....	41.2	44.4+	25.5	25	23	....	9.4	....	26.9	15.65
Resilience, inch-pounds to 700 pounds.	4.06	....	3.5	....	1.4	5.38	15	19.5	21	....	28.8	....	2.03	1.08
Shockresilience, foot-pounds.	76.1	....	(?)76	....	<115	......	79.2	.....	80.0	....	53.6	....	55.0	......
Ratio to tensile resilience.	2.9	....	2.8	....	2.8	......	3.1	.....	3.4	....	*	....	2.04	......
Area of fracture, %..	70	....	(?)64	....	60	......	64	.....	77	....	73	....	69	......
Shearing	4.45	4.31	4.52	4.31	4.94	4.87	4.17	4.17	4.06	3.81	3.60	3.66	5.31	7.5
Bending	87°	....	165°	....	43°	40°	285°	.....	360°+	....	27°	....	264°(?)	30°

* See Table II, anom. † Actual.

Comparing the indications given by these curves and the bending test with the results of firing in the éprouvette, the following deductions may safely be drawn:

GENERAL DEDUCTIONS.

Predication of metals apt to burst.

1. That with metals of standard form and section, having at 700 pounds strain an area of resilience less than 10 inch-pounds, and opening after bending at less than 200°, rupture is apt to occur from bursting in the flange—a failure which can only be remedied by the use of interior gas checks, since increasing the thickness of the metal will probably only increase the likelihood to rupture from bending.

Predication of metals apt to shear.

2. In cartridges parting by shearing, however, it has been proved by experiment that the strength is increased in proportion to the thickness

of the walls at the shearing point; consequently, in metal ductile enough not to be subject to the former intractable defect, the task of strengthening the cartridge becomes comparatively a simple one, as it merely involves thickening the walls to the full extent allowed by the special construction of the cartridge case. (See Appendix, page 681.)

NOTE.—An exception to this rule appears in the case of annealed brass, which, notwithstanding its low area of resilience at 700 pounds and its low angle of opening after bending, yet behaves in the éprouvette, when annealed after heading, precisely as does the far more ductile Moffet metal. This presents an anomaly which can only be explained by a more protracted research, from which I was unfortunately debarred by a lack of the necessary material. Annealing the head of the brass cartridge before priming it also seemed to increase its strength greatly, with but little resistance to extraction from sticking.

Comparative value of merchant and Moffet copper.

3. The merchant copper, judging from the indications of the éprouvette, is, if anything, a little better than the Moffet copper, and consequently, if we should neglect the teachings of the wide experience of the department with the latter metal, might be preferred to it as a standard. Its lower bending value, however, 285° *vs.* 360° +, seems to render it possible that, on an extended trial, cartridge cases made from it might be found apt to burst in the fold. It is also apparently less uniform. (See Table II.) Its greater hardness may increase the cost of manufacture.

ESSENTIAL CHARACTERISTICS OF GOOD CARTRIDGE METAL FOR SERVICE CARTRIDGE.

Taking everything into consideration, I am inclined to think that a metal having a bending value of 360° +, with an ultimate strength of about 1,200 pounds and an ultimate extension of about 0''.30, and having an area of resilience at 700 pounds of about 20 inch-pounds, would be apt to give the most satisfactory results.

NOTE.—The Moffet and merchant curves themselves give limits within which good work will almost certainly follow.

Minor characteristics of good cartridge metal.

If with the above conditions can be harmonized a resistance to tensile shock applied through a falling weight of 16.5 pounds of about 3.2 times the area of resilience due to tensile strain; and a punching resistance to penetration by a falling weight of 3 pounds operating on a sharp half-inch punch and die of about 4.0 foot-pounds; and if the areas of rupture, due to tensile strain, be found about 65 per cent. of the original areas of least resistance; then it may be said that the best metal has been found for the manufacture of the service cartridge.

Request for a Thurston testing machine.

I hope that the apparent dogmatism of these remarks may be thought due to nothing but to my desire to express concisely the teachings of the experiments I have herein described. The apparatus used in them is of the rudest character. Its entire cost, aside from that of old materials and tools utilized for its purpose, was about $30.

There is, therefore, a possibility of error in the premises from which the conclusions above stated were deduced.

If, however, no greater fault in the method adopted in the inquiry should be revealed by the light of criticism, I would advise the prosecution of these inquiries with a more delicate testing machine, capable especially of regarding the circumstances of tensile strain below 700 pounds.

I am now in correspondence with Professor Thurston, of the Stevens Institute, in regard to the adaptation of his torsional testing machine to the examination of sheet cartridge metals, and he has now in hand specimens of the different materials herein discussed. If he should be able to alter his machine so as to obtain as good and interesting results as those reported in his experiments with specimens of the ordinary circular section, I would urgently advise its purchase. There is no other method known to me whereby the circumstances affecting the life of a specimen undergoing strain can be so accurately determined as from the autobiography which the Thurston machine records. I believe such a machine would be of very general value throughout the department. It is much used by the Pennsylvania Railroad Company and others.

Chemical analysis.

In combination with this I would advise a chemical analysis involving specific gravities of the various metals herein reported on or to be hereafter tried. I am informed that the laboratory at Watertown Arsenal is well prepared for such investigations.

To give a categorical answer to the inquiry eliciting this report, I would respectfully report that I find that, except the Moffet, the Merchant copper is the only metal tested which I consider suitable for the manufacture of the service cartridge. A possible exception to this, as already suggested, may exist in the case of brass annealed in the head before priming.

In connection with this report are submitted drawings, plates I to VIII, inclusive, and an abstract from the record of tests, giving the data from which the conclusions above mentioned were derived.

APPENDIX.

It was found necessary to determine whether it was safe to assume, in constructing the preceding curves, that a correction should be made for slight differences from the standard (thickness of 0''.030), by increasing or diminishing the indicated strains in proportion to the sectional areas of the specimens tested.

Accordingly, specimens of Moffet copper of the standard form, but varying in thickness from 0''.037 to 0''.025, were tested.

From the results obtained under tensile strain the curves *a f*, Plate VIII, were plotted, as for the standard thickness, by diminishing or increasing the strains corresponding to the various elongations.

At the same time, in order to ascertain the variation between different strips of the same lot of copper and between different lots of copper, the curves *d* and *e* were deduced, *e* being from old copper that had been about the shop for many months or years. Preceding curves had all been plotted from the mean results of several specimens taken from the same sheet of copper.

It appears that the following conclusions may be drawn from the examination of these curves:

That it is not safe to act upon the assumption above noted, not only on account of the extent of accidental variations between various specimens of presumably the same origin, but also on account of a certain intrinsic strength which appears to pertain to small sections.

The experiments have not been sufficiently extended to make these conclusions positive, but it seems as if the skin of hard metal resulting from rolling must probably be of nearly the same absolute thickness in any metal, and hence of greater proportionate thickness in the thinner metals.

As much of the strength of the metal results from the resistance of this skin, the greater proportionate strength of the thin metal is probably explained.

Examples: The *actual* curve (not plotted) of 0''.031 copper is below that of curve *c* of the 0''.030 section, and by assimilation it is necessarily still further reduced to a position below that of any other thickness. An examination of the steel curves, Plate VI, confirms these opinions. The curve *a*, Plate VIII, opposes them. This may be due to the fact of this copper having been made for a special form of reloading cartridge.

The curve *d* shows that it is reasonably safe to take the results from a single sheet as typical. The curve *e* would indicate either that the manufacturer has recently increased the stiffness of the metal or that its initial tension is relaxed by time.

The curves *g*, *h*, *i*, *j*, *k*, Plate VIII, seem generally to confirm these opinions. As a rule, the smaller the section the stiffer proportionately is the specimen.

The curved pieces give stiffer results than the straight ones, but naturally the latter give vastly greater ultimate extensibility.

VERIFICATION OF THEORY OF RESISTANCE TO SHEARING BY GAS PRESSURE.

In order to test the theory of resistance enunciated on page 678, I fired from the éprouvette several cup-anvil cartridges made from reloading cartridge metal 0''.037 thick, in comparison with the service cup-anvil cartridge made from 0''.030 metal.

Calling the distance *c d*, Plate I, Fig. 2 $=l$, and the thickness $d\,e=t$, the relative strength of the cartridges will be expressed by the formula

$$s=\frac{t}{l}.$$

In the service cartridge $t=0''.025$—and for l, cartridge head space, $=0''.70 \therefore l=.070-.030=.040$.

In the thickened cartridge $t=0''.03$ and $l=.070-.037=.033$.

$$s=\frac{25}{40}=.625. \quad s'=\frac{30}{33}=.909$$

$$s : s' :: 625 : 909.$$

Owing to certain changes in the éprouvette the service cartridge on this occasion sheared at 17 grains of English rifle powder. Supposing the increase in pressure to be directly proportionate to the charge, which for small variations is approximately true, the strength of the thickened cartridge might be deduced from the proportion

$$s : s' :: 625 : 909 :: 17 : x. \quad x=24.7 \text{ grains.}$$

By experiment one thickened cartridge sheared at 25 grains, four others filling the recess by swelling so as to prevent shearing. Experimental Record, Frankford Arsenal, p. 75.

MEASURING WHEEL.

The little instrument shown, Plate IV, Fig. 1, was adapted to the convenient measurement of the areas of resilience by the following additions to the ordinary opisometer:

The edge of the frame was graduated so as to show directly the number of inches traveled by wheel to within the length of one turn; fractions of turns could be read from the side of the wheel. Both readings could be accurately made by means of the traveling pointer shown, which also served as a datum point in taking the sum of a number of disconnected lines.

The mode of using the instrument was as follows: The wheel was run over all the ordinates of the curve in succession, starting and stopping the wheel in every case with the pointer on the end of the line.

The total reading in inches divided by 4 gives the area in foot-pounds. For calling $l =$ length of sum of ordinates in inches, and $n =$ number of ordinates, $\frac{l}{n}$ equals length of the mean ordinate in inches. As the scale is 3 spaces = one inch, $\frac{l}{n} \times 3 =$ number of space sin mean ordinate; and $\frac{l}{n} \times 3 \times n = 3l =$ area of curve in squares = inch-pounds.

For foot-pounds divide by 12, or $\frac{3l}{12} = \frac{l}{4} =$ area in foot-pounds.

Abstract of record of mechanical tests.

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength.					Drop test.									Shearing.					Bending.		Remarks.
				Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	
1878. Feb. 11	45	Ansonia copper (XII).	1 x .03	800	.015																				
				900	.03																				
				1000	.05																				
				1100	.075																				
				1200	.105																				
				1300	.155																				
				1400	.27	.852 x .024	.020	67																	
Feb. 11	46	...do	1 x .03	800	.015	....	....	....	....	..	....	....	....	....	....	....	..	..	..	....	....	....	....	....	See No. 31.—In this case D = 0″.10 again, though the extension is only .265 *vs.* .32. See No. 133.
				900	.03																				
				1000	.05																				
				1100	.075																				
				1200	.10																				
				1300	.15																				
				1400	.265	.873 x .024	.021	70																	
Feb. 11	47	...do	1 x .03	800	.01																				
				900	.03																				
				1000	.05																				
				1100	.075																				
				1200	.10																				
				1300	.15																				
				1400	.265	.901 x .024	.022	73																	
Means	....	...do	1 x .03	800	.0133																				
				900	.03																				
				1000	.05																				
				1100	.075																				
				1200	.102																				
				1300	.152																				
				1400	.266	....	....	70																	
Feb. 11	81	...do	1 x .03	....	....	....	....	....	16.5	1	4.6	76.1	......	.30	.865 x .023	.020	67	..	..	....	....	....	....	....	Could see daylight through crease.
Feb. 11	82	...do	1 x .03	....	....	....	....	....	16.5	1	4.6	76.1	......	part'd	.884 x .024	.021	70								

Jan. 11	117	....do	1.57 x .03															3		1.5	4.5	not thro'			Irregular results; same for 1.479 and 1.458.
Jan. 11	118	....do	1.57 x .03															3		1.406*	17.8 4.456	through			Irregular; see above; same for 1.492, 1.479, and 1.467; *should be, say, 1.483.
Jan. 11	119	Same, annealed	1.57 x .03															3		1.437	4.31	not thro'			Same for 1.433; 1 time each.
Jan. 11	120	....do	1.57 x .03															3	1	1.437	4.31	through			2 times; probably about right.
Jan. 21	110	Ansonia copper (XII).	0.25 x .03																				1200	87	Mean of 5 trials, ranging from 80°-90°.
Feb. 11	48	Ansonia copper (XV).	1 x .031	700 800 900 1000 1100 1200 1300 1400	.01 .025 .04 .055 .085 .11 .16 .27	.875 x .025	.022	70																	
Feb. 11	49	....do	1 x .031	700 800 900 1000 1100 1200 1300 1400	.01 .03 .04 .055 .08 .11 .165 .27	.878 x .025	.022	70																	
Feb. 11	50	....do	1 x .031	700 800 900 1000 1100 1200 1300 1400	.01 .025 .045 .06 .09 .11 .165 .27	.871 x .025	.022	70																	

* See next page.

Abstract of record of mechanical tests—Continued.

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength.					Drop test.									Shearing.					Bending.		Remarks.
				Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	
1878. Means	....	Ansonia copper (XV).	1 x .031	700 800 900 1000 1100 1200 1300 1400	.01 .027 .042 .057 .085 .11 .163 .27	....	.....	70																	
Feb. 11	65	....do	1 x .031	....	....	....	.....	.....	16.5	1 2 3	4.25 .50 .50	70.1 8.25 8.25	...... 78.35 86.6	.25 .29 part'd	.86 x .024	.021	67								
Feb. 11	66	....do	1 x .031	....	....	....	.....	.....	16.5	1 2 3	4.33 .5 .5	71.5 8.25 8.25	...... 79.75 88.00	.25 .28 part'd	.862 x .023	.020	64	..	..	.....	.....	....	....	....	No more specimens on hand of this metal. Value probably=76. From proportion of results of experiments, No. 65 : 71 :: 85 : x ∴ x =76.
Jan. 11	121	....do	1.57 x .031	....	....	....	.....	.....	....	..	....	....	.....	.....	....	....	..	3	1	1.5	4.5	not thro'.	....	....	4 times.
Jan. 11	122	....do	1.57 x .031	....	....	....	.....	.....	....	..	....	....	.....	.....	....	....	..	3	1	1.507	4.52	through .	....	....	3 times; 1.5 thro' once.
Jan. 11	123	Same, annealed ..	1.57 x .031	....	....	....	.....	.....	....	..	....	....	.....	.....	....	....	..	3	1	1.433	4.3	not thro'.	....	....	4 times.
Jan. 11	124	....do	1.57 x .031	....	....	....	.....	.....	....	..	....	....	.....	.....	....	....	..	3	1	1.437	4.31	through .	....	....	4 times.
Feb. 21	111	Ansonia copper (XV).	0.25 x .031	....	....	....	.....	.....	....	..	....	....	.....	.....	....	....	..	..	..	.....	.....	....	1200	165	Mean of 4 trials from 130°–245°.

*Feb. 11	29	Ansonia brass	1 x .03	900	.005																				This is the first clip specimen pulled.
Feb. 11	29	....do	1 x .03	1000 1100 1200 1300 1400 1500 1600 1700 1800	.015 .025 .04 .065 .08 .115 .16 .215 .32	.862 x .023	.020	67																	
Feb. 11	30	....do	1 x .03	900 1000 1000 1200 1300 1400 1500 1600 1700 1800	.005 .015 .025 .045 .065 .09 .12 .16 .225 .325	.843 x .024	.020	67																	
Feb. 11	31	....do	1 x .03	1000 1100 1200 1300 1400 1500 1600 1700 1800	.010 .025 .04 .055 .085 .115 .15 .21 .32	.850 x .024	.020	67																	To ascertain the amount of extension beyond the measured inch, the broken parts of this specimen were overlaid, so that the initial points of the inch were again 1″ apart. The length then between clips = 4.12. The original length = 4.02, D = 0″.10. See No. 46 and No. 133.
Means		....do	1 x .03	900 1000 1100 1200 1300 1400 1500 1600 1700 1800	.005 .013 .025 .042 .062 .085 .117 .157 .217 .322			67																	
Feb. 15	96	....do	1 x .03						16.5	1 2	5.17 1.0	85.2 16.5	...... 101.7	.24 .295											

Abstract of record of mechanical tests—Continued.

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength.					Drop test.									Shearing.					Bending.		Remarks.
				Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	
1878. Feb. 15	96	Ansonia brass	1 x .03							3	0.25	4.1	105.8	.30											
										4	0.25	4.1	109.9												
										5	1.00	16.5	126.4	.36											
										6	0.5	8.25	134.6	part'd	.830 x .023	.019	63								
Feb. 15	97	....do	1 x .03						16.5	1	5.33	87.94	87.94	.27											
										2	1.0	16.5	104.44	.325											
										3	1.0	16.5	120.94	.37											Crease began in center.
										4	0.5	8.25	129.19	part'd	.848 x .022	.019	63								This height was the utmost attainable on the rod.
Feb. 15	98	....do	1 x .03						22	1	5.0	110.0	110	part'd	.840 x .022	.019	63								The weight was increased so as to allow for its low fall.
Feb. 15	99	....do	1 x .03						22	1	4.5	99	99	part'd	.835 x .022	.018	60								This was the last specimen of brass that could be found. From other ratios between effect of 16.5 and 22 lbs. weights, value = 115 foot-pounds.
Jan. 11	125	....do	1.57 x .03															3	1	1.647	4.94	not thro'.			2 times.
																					19.75				
Jan. 11	126	....do	1.57 x .03															3	1	1.638	4.94	through.			1 time; 1.642, 1 time; 1.646, 2 times; 1.65, 3 times; say 1.646.

Feb. 15	106	....do	0.25 x .03																				1200	42	Mean of 4 trials ranging from 40°-45°.
Feb. 15	104	Ansonia brass (annealed).	1 x .03	700 800 900 1000 1100 1200 1300 1400 1500 1600 1650	.005? .02 .03 .05 .075 .10 .13 .165 .22 .35 .39	.819 x .023	;019	63																	
Jan. 11	127	....do	1.57 x .03															3	1	1.667	5.00	not thro'.			1 time; same for 1.625, 1 time; 1.604, 3 times; 1.592, 1 time; 1.583, 3 times.
Jan. 11	128	....do	1.57 x .03															3	1	1.583	19.5 4.87	through.			1 time; probably average about 1.625.
Feb. 15	105	....do	0.25 x .03																				1200	40	Mean of 8 trials ranging from 40°-40°.
Feb. 20	131	Merchant copper.	1 x .031	600 700 800 900 1000 1100 1200 1300	.015 .025 .045 .065 .09 .13 .195 .295	.857 x .024	.021	67																	
Feb. 20	132	....do	1 x .031	500 600 700 800 900 1000	.005 .015 .025 .04 .055 .085																				
Feb. 20	132	Merchant copper	1 x .031	1100 1200 1300	.13 .22 .28	.850 x .024	.020	64																	

Abstract of record of mechanical tests—Continued.

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength.					Drop test.									Shearing.					Bending.		Remarks.
				Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	
1878. Feb. 20	133	Merchant copper.	1 x .031	500	.005	....	....	....	....	..	....	....	....	....	....	....	..	..	..	....	....	....	....	....	Total elongation of specimen = 0″.1 + .29. See Nos. 31 and 46.
				600	.015																				
				700	.025																				
				800	.045																				
				900	.065																				
				1000	.085																				
				1100	.13																				
				1200	.21																				
				1300	.29	.842 x .024	.020	64																	
Feb. 20	134	....do	1 x .031	500	.005																				
				600	.015																				
				700	.02																				
				800	.05																				
				900	.07																				
				1000	.09																				
				1100	.135																				
				1200	.23																				
				1300	.29	.850 x .024	.020	64																	
Means .	......	....do	1 x .031	500	.005																				
				600	.015																				
				700	.025																				
				800	.04																				
				900	.064																				
				1000	.087																				
				1100	.13																				
				1200	.214																				
				1300	.29	....	....	64.75																	
Feb. 20	148	....do	1 x .031	....	....	....	....	....	22	1	3.08	67.8	67.8	part'd	.848 x .024	.020	64	..	..	....	....	....	....	....	See No. 152, where, with W = 16.5, 79.2 foot-pounds required.

Feb. 21	151	....do	1 x .031						16.5	1	4.75	78.4	78.4	0.3	.862 x .024	.021	67								Creased.
Feb. 21	152	....do	1 x .031						16.5	1	4.8	79.2	79.2	part'd	.850 x .024	.020	64								See No. 148, where, with W = 22 pounds, 67.8 foot-pounds sufficient.
Feb. 23	166	....do																3	1	1.385	4.155	not thro'.			
																				1.39	4.17	through.			
Feb. 23	167	....do																3	1	1.38	4.14	not thro'.			
																				1.385	4.155	through.			Mean, 4.16 foot-pounds through.
Feb. 20	150	....do	0.25 x .031																				1200	285	Mean of 4 trials, varying from 200°–320°.
Feb. 20	135	Merchant copper (annealed).	1 x .031	500	.01																				
				600	.02																				
				700	.03																				
				800	.05																				
				900	.07																				
				1000	.10																				
				1100	.13																				
				1200	.22																				
				1300	.30	.848 x .025	.021	67																	
Feb. 20	136	....do	1 x .031	500	.005																				
				600	.01																				
				700	.025																				
				800	.04																				
				900	.08																				
				1000	.095																				
				1100	.125																				
				1200	.21																				
				1300	.28	.850 x .025	.021	67																	
Feb. 20	137	....do	1 x .031	500	.01																				
				600	.02																				
				700	.03																				
				800	.05																				
				900	.075																				
				1000	.10																				
				1100	.13																				
				1200	.205																				
				1300	.29	.848 x .024	.020	64																	

Abstract of record of mechanical tests—Continued.

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength.					Drop test.									Shearing.					Bending.		Remarks.
				Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	
1878. Feb. 20	138	Merchant copper (annealed).	1 x .031	500	.01																				
				600	.02																				
				700	.04																				
				800	.055																				
				900	.075																				
				1000	.105																				
				1100	.14																				
				1200	.215																				
				1300	.295	.852 x .024	.020	64																	
Means	....	....do	1 x .031	500	.09																				
				600	.017																				
				700	.031																				
				800	.049																				
				900	.075																				
				1000	.100																				
				1100	.131																				
				1200	.212+																				
				1300	.295	....	....	65.5																	
Feb. 23	168	....do	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	1	1.385	4.155	Not thro'.			
																				1.39	4.17	Through.	....	....	Tried on same piece. Mean, 4.17 through.
Mar. 9	176	Moffet copper....	1 x .03	500	.005	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	To compare closely effect of slightly varying thickness on elongation and ultimate strength, see Nos. 51, 52, and 53.
				600	.02																				
				700	.04																				
				800	.065																				
				900	.10																				
				1000	.16																				
				1100	.29	.859 x .22	.019	63																	

Mar. 9	**177**	**do**	**1 x .03**	500 600 700 800 900 1000 1100	.005 .02 .035 .065 .105 .155 .30	.862 x .22	.019	63																	Same.
Mar. 9	**178**	**do**	**1 x .03**	500 600 700 800 900 1000 1100	.005 .02 .035 .06 .10 .155 .30	.862 x .22	.019	63																	Same.
Means		**do**	**1 x .03**	500 600 700 800 900 1000 1100	.005 .02 .036 .063 .102 .156 .296			63																	
Feb. 11	**71**	**do**	**1 x .03**						16.5	1 2 3 4	4.25 .25 .25 .25	70.1 4.1 4.1 4.1	 74.2 78.3 82.4	.30 .325 .35 part'd	.834 x .024	.020	67								
Feb. 11	**75**	**do**	**1 x .03**						16.5	1	4.9	80.8		part'd	.838 x .024	.020	67								
Feb. 11	**77**	**do**	**1 x .03**						16.5	1	4.85	80.0		.36	.830 x .024	.020	67								Creased so as to show daylight through. (See No. 83.)
Feb. 11	**85**	**do**	**1 x .03**						16.5	1	4.85	80.0		part'd	.898 x .025	.022	77								
Feb. 22	**158**	**do**	**1 x .03**						22	1	3.15	69.3	69.3	part'd	.825 x .024	.020	67								See No. 85, where, with 16.5 pounds weight, 80 foot-pounds required.
Jan. 11	**113**	**do**	**1.57 x .03**															3	1	1.35	4.05	not thro'			3 times.
	114	**do**	**1.57 x .03**															3	1	1.353	4.06	through			2 times.
Jan. 15	**109**	**do**	**0.25 x .03**																				1200	360+	Mean of 3 trials all alike; no crack discernible.

Abstract of record of mechanical tests—Continued.

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength. Strain in pounds.	Tensile strength. Extension of 1″.0.	Tensile strength. Dimensions of fracture.	Tensile strength. Area of fracture.	Tensile strength. Reduced area, %.	Drop test. Weight in pounds.	Drop test. Number of blow.	Drop test. Height in feet.	Drop test. Foot-pounds of blow.	Drop test. Total foot-pounds.	Drop test. Extension of 1″.0.	Drop test. Dimensions of fracture.	Drop test. Area of fracture.	Drop test. Reduced area, %.	Shearing. Weight in pounds.	Shearing. Number of blow.	Shearing. Height in feet.	Shearing. Foot-pounds of blow.	Shearing. Effect.	Bending. Pressure.	Bending. Opening in degrees.	Remarks.
Jan. 11	115	Moffet copper, annealed.	1.57 x .03	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	1	1.267	3.8	not thro'.	....	....	3 times not thro'; 1 time through.
	116	....do	1.57 x .03	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	1	1.27	3.81	through.	....	....	2 times through; 1 time not thro'gh.
Feb. 11	54	Pure copper, (Moffet's.)	1 x .03	400 500 600 700 800 900	.01 .025 .045 .055 .08 .15	.96 x .025	.024	80																	
Feb. 11	55	....do	1 x .03	400 500 600 700 800 900 1000	.01 .02 .04 .055 .08 .11 .16	.957 x .025	.024	80																	
Feb. 11	56	....do	1 x .03	400 500 600 700 800 900 1000 1100	.005 .02 .035 .05 .07 .105 .155 .225	.907 x .024	.022	73																	

Feb. 11	57	....do	1 x .03	300 400 500 600 700 800 900 1000	.005 .02 .03 .04 .055 .08 .115 .155	.915 x .025	.023	77																	
Means	....	....do	1 x .03	300 400 500 600 700 800 900 1000	.005 .011 .024 .04 .054 .078 .12 .155	....	.....	77.5																	
Feb. 11	60	....do	1 x .03	....	.....	....	.....	.....	16.5	1	3.3	55.0	55.0	part'd	.902 x .024	.022	73								
	61	....do	1 x .03	....	.....	....	.....	.....	16.5	1	3.25	53.6	53.6	0.25	.908 x .025	.023	77	..	..	......	.....	....	.....	.....	Began tearing on edge.
	62	....do	1 x .03	....	.....	....	.....	.....	16.5	1	3.25	53.6	53.6	part'd	.923 x .024	.022	73								
Feb. 23	162	....do	1.57 x .03	....	.....	....	.....	.....	.....	..	....	.....	.....	.....	....	.....	..	3 3	1 1	1.195 1.2	3.585 3.6	not thro'. through.			
	163	....do	1.57 x .03	....	.....	....	.....	.....	.....	..	....	.....	.....	.....	....	.....	..	3 3	1 1	1.198 1.2	3.59 3.6	not thro'. through.	.....	.....	Mean 3.6 foot-lbs. through.
Feb. 15	107	....do	0.25 x .03	....	.....	....	.....	.....	.....	..	....	.....	.....	.....	....	.....	..	..	..	......	.....	....	1200	27	Mean of 4 trials ranging from 25° to 30°.
Feb. 23	164	Same, annealed ..	1.57 x .03	....	.....	....	.....	.....	.....	..	....	.....	.....	.....	....	.....	..	3 3	1 1	1.215 1.22	3.645 3.66	not thro'. through.	.....	.....	Mean 3.65 foot-lbs. through.
	165	....do	1.57 x .03	....	.....	....	.....	.....	.....	..	....	.....	.....	.....	....	.....	..	3 3	1 1	1.21 1.22	3.63 3.66	not thro'. through.			
Feb. 15	108	....do	0.25 x .03	....	.....	....	.....	.....	.....	..	....	.....	.....	.....	....	.....	..	..	..	......	.....	....	1200	32	Mean of 5 trials varying from 25° to 40°.
Jan. 11	22	Steel............. (Martin's Bessemer.)	0.5 x .026	500 600 700 800	.01 .03 .06 .17	.460 x .023	.0102	77	.....	..	....	.....	.....	.....	....	.....	..	..	..	......	.....	....	.....	.....	The proportionate strains for an area of least resistance = 1. x 0.03, are for— 500 lbs....1154 600 lbs....1384 700 lbs....1615 800 lbs....1845

Abstract of record of mechanical tests—Continued.

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength. Strain in pounds.	Tensile strength. Extension of 1″.0.	Tensile strength. Dimensions of fracture.	Tensile strength. Area of fracture.	Tensile strength. Reduced area, %.	Drop test. Weight in pounds.	Drop test. Number of blow.	Drop test. Height in feet.	Drop test. Foot-pounds of blow.	Drop test. Total foot-pounds.	Drop test. Extension of 1″.0.	Drop test. Dimensions of fracture.	Drop test. Area of fracture.	Drop test. Reduced area, %.	Shearing. Weight in pounds.	Shearing. Number of blow.	Shearing. Height in feet.	Shearing. Foot-pounds of blow.	Shearing. Effect.	Bending. Pressure.	Bending. Opening in degrees.	Remarks.
1878. Jan. 11	23	(Steel) Martin's Bessemer.	0.5 x .026	500	.01																				These specimens were all held by friction only, but showed no depression of extremities after strain.
				600	.025																				
				700	.06																				
				800	.17	.469 x .023	.011	84																	
	24	....do	0.5 x .026	500	.01																				Same.
				600	.03																				
				700	.05																				
				800	.16	.459 x .023	.0112	84																	
Means		....do	0.5 x .026	500	.01																				See curves C C′, Plate VI.
				600	.028																				
				700	.057																				
				800	.167			81.66																	
Mar. 21	192	....do	1 x .03	1100	.005																				The steel was of very uneven thickness, but parts were found of three strips giving this thickness. It ran in the same strip from .030 to .034; mean thickness .032.
				1200	.01																				
				1300	.02																				
				1400	.035																				
				1500	.075																				
				1600	.155	.92 x .025	.023	77																	

Mar. 21	193	...do	1 x .03	1200 1300 1400 1500 1600	.005 .015 .03 .06 .125	.922 x .023	.021	71																
Mar. 21	194	....do	1 x .03	1300 1400 1500 1600	.005 .025 .06 .10	.928 x .025	.023	77	.....	..	.....	.....	.....	.....	....	....	..	..	..	.....	.....	....	....	....	See curve A, Plate VI.
Means	....	....do	1 x .03	1100 1200 1300 1400 1500 1600	.005 .0075 .013 .03 .065 .126	....	.....	75																
Feb. 15	93	....do	1 x .026	....	....	....	....	....	16.5	1	3.25	53.6	53.6	......	.902 x .019	.017	65	..	..	.....	.....	....	....	....	Nearly parted.
Feb. 15	94	....do	1 x .026	....	....	....	....	....	16.5	1	3.33	55.0	55.0	part'd	.920 x .020	.018	69	..	..	.....	.....	....	....	....	For 0.03 x 1 section = 63.5 foot-pounds.
Feb. 15	95	....do	1 x .026	....	....	....	....	....	16.5	1	3.3	54.3	54.3	.22	.905 x .020	.018	69	..	..	.....	.....	....	....	....	Fracture ⅓ across.
Jan. 11	129	....do	1.57 x .026	....	....	....	....	....	....	..	....	....	.....	......	....	....	..	3	1	1.767	5.3	not thro'.	....	....	One time; of 5 lower blows none went through.
Jan. 11	130	....do	1.57 x .026	....	....	....	....	....	....	..	....	....	.....	......	....	....	..	3	1	1.77	5.31	through.	....	....	Two times; metal already annealed. For .03 thick = 61.3.
Mar. 24	199	....do	1.57 x .030	....	....	....	....	....	....	..	....	....	.....	......	....	....	..	3 3	1 1	2.5 2.45	7.50 7.35	through. not thro'.			
Feb. 20	149	....do	0.25 x .026	....	....	....	....	....	....	..	....	....	.....	......	....	....	..	..	..	.....	.....	....	1200	264	Mean of 5 trials ranging from 160°–360°. Hard to tell exactly owing to closeness of joint at bend.
Mar. 23	195	....do	0.25 x .030	....	....	....	....	....	....	..	....	....	.....	......	....	....	..	..	..	.....	.....	....	1200	30	Two at 30° and one at 28°.

Abstract of record of mechanical tests—Continued.

APPENDIX.—I. *Effect of varying thickness of standard form.*

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength.					Drop test.									Shearing.					Bending.		Remarks.
				Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	
1878. Mar. 13	179	Moffet copper	1 x .037	800	.005																				To observe effect of varying section. The pressures for a 1 x .030 section corresponding to these are 650 pounds, 730, 810, 892, 973, 1054, 1094, 1114.
				900	.015																				
				1000	.045																				
				1100	.07																				
				1200	.105																				
				1300	.155																				
				1375	.30	.867 x .024	.021	57																	
Mar. 13	180	....do	1 x .037	800	.01																				
				900	.025																				
				1000	.055																				
				1100	.075																				
				1200	.11																				
				1300	.16																				
				1350	.22																				
				1375	.305	.852 x .029	.025	67																	
Mar. 13	181	....do	1 x .037	800	.005																				
				900	.025																				
				1000	.045																				
				1100	.075																				
				1200	.105																				
				1300	.155																				
				1350	.20																				
				1375	.305	.878 x .024	.021	57																	
Means		....do	1 x .037	800	.007																				See curve *a*, Plate VIII.
				900	.022																				
				1000	.048																				
				1100	.073																				
				1200	.106																				
				1300	.156																				
				1350	.21																				
				1375	.303			60.33																	

Feb. 11	51	....do	1 x .031	700	.05	....	......	......	Not watched below 700 pounds.
				800	.075				
				900	.11				
				1000	.155				
				1100	.265				
				1200	.32	.850 x .024	.020	67	
Feb. 11	52	....do	1 x .031	400	.01				
				500	.02				
				600	.035				
				700	.05				
				800	.08				
				900	.11				
				1000	.155				
				1100	.27				
				1200	.315	.851 x .023	.020	67	
Feb. 11	53	....do	1 x .031	400	.01				
				500	.02				
				600	.035				
				700	.05				
				800	.075				
				900	.105				
				1000	.16				
				1100	.265				
				1200	.32	.84 x .024	.020	67	
Means	.....	....do	1 x .031	400	.01	....	......	......	See curve *b*, Plate VIII.
				500	.02				
				600	.035				
				700	.05				
				800	.077				
				900	.108				
				1000	.157				
				1100	.267				
				1200	.318	....	......	67	
Mar. 18	182	Moffet copper.... (current stock.)	1 x .03	600	.01	....	......	......	The specimens following to 191, inclusive, were all taken from different strips of copper, to attempt to discover variation in general product. Sets of specimens previously tried, were cut from the same strip generally.
				700	.025				
				800	.05				
				900	.075				
				1000	.14				
				1100	.295	.844 x .023	.19	63	

Abstract of record of mechanical tests—Appendix—Continued.

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength.					Drop test.									Shearing.					Bending.		Remarks.
				Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	
1878. Mar. 18	183	Moffet copper (current stock).	1 x .03	600	.015																				Nos. 182, 183, 184, were from different strips of the stock in current service at this time. See above and below.
				700	.03																				
				800	.06																				
				900	.10																				
				1000	.15																				
				1100	.30	.839 x .023	.19	63																	
Mar. 18	184	....do	1 x .03	600	.015																				Same.
				700	.03																				
				800	.065																				
				900	.10																				
				1000	.15																				
				1100	.29	.858 x .024	.21	70																	
Means		....do	1 x .03	600	.012																				See curve *d*, Plate VIII.
				700	.028																				
				800	.058																				
				900	.092																				
				1000	.15																				
				1100	.295			65.33																	
Mar. 13	185	Moffet copper (old stock).	1 x .03	500	.01																				Nos. 185, 186, and 187 were from old copper laid aside for several years. They did not appear to have been quite as much rolled as 182 to 184.
				600	.035																				
				700	.05																				
				800	.085																				
				900	.125																				
				1000	.19																				
				1100	.325	.845 x .023	.19	63																	
Mar. 13	186	....do	1 x .03	500	.015																				Same.
				600	.03																				
				700	.05																				

				800	.08																			
				900	.12																			
				1000	.18																			
				1100	.315	.857 x .023	.20	67																
Mar. 18	187	....do	1 x .03	500	.015																			Same.
				600	.03																			
				700	.05																			
				800	.085																			
				900	.125																			
				1000	.20																			
				1100	.31	.855 x .023	.020	67																
Means		....do	1 x .03	500	.013																			See curve *e*, Plate VIII.
				600	.032																			
				700	.05																			
				800	.083																			
				900	.123																			
				1000	.19																			
				1100	.316			65.66																
Mar. 18	188	Moffet copper (pistol copper).	1 x .025	400	.01																			To further compare influence of section; also taken from different strips of copper.
				500	.025																			
				600	.05																			
				700	.075																			
				800	.12																			
				900	.18																			
				1000	.305	.873 x .019	.0166	66																
Mar. 18	189	....do	1 x .025	400	.01																			
				500	.025																			
				600	.045																			
				700	.075																			
				800	.12																			
				900	.19																			
				1000	.305	.850 x .019	.0161	64																
Mar. 18	190	....do	1 x .025	400	.01																			
				500	.025																			
				600	.05																			
				700	.07																			
				800	.11																			
				900	.175																			
				1000	.305	.865 x .019	.0164	65																
Mar. 18	191	....do	1 x .025	400	.005																			
				500	.025																			
				600	.04																			
				700	.07																			
				800	.105																			
				900	.175																			
				1000	.30	.853 x .020	.0170	68																

Abstract of record of mechanical tests—Appendix—Continued.

				Tensile strength.					Drop test.									Shearing.					Bending.		
Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	Remarks.
1878. Means	....	Moffet copper (pistol copper).	1 x .025	400	.009																				See curve *f*, Plate VIII.
				500	.025																				
				600	.046																				
				700	.072																				
				800	.114																				
				900	.180																				
				1000	.304			65.75																	
Mar. 1	159	Steel, (Martin's Bessemer).	1 x .026	900	.005																				The corresponding strains for a section 1 x .030 are 1040, 1146, 1385, 1500, 1615, 1730, and 1840 pounds. By constructing a curve on this supposition we obtain one from 100–200 pounds lower and about 0″.06 longer than in constructing it from the data given by the 0.5 x .026 section, see Nos. 22, 23 and 24. Showing that the apparent strength per square inch is increased by diminishing the cross-section of the specimen,
				1000	.02																				
				1100	.03																				
				1200	.04																				
				1300	.06																				
				1400	.075																				
				1500	.13																				
				1600	.23	.912 x .02	.018	70																	

									and that it is only safe to take *absolute* results for comparison, placing them mechanically on as nearly the same footing as possible.
Mar. 1	160	....do	1 x .026	900	.01				
				1000	.025				
				1100	.03				
				1200	.045				
				1300	.06				
				1400	.08				
				1500	.15				
				1600	.23	.915 x .02	.018	70	
Means		....do	1 x .026	900	.0075	....	.....		See curves B, B′, Plate VI.
				1000	.0225				
				1100	.03				
				1200	.0425				
				1300	.06				
				1400	.0775				
				1500	.14				
				1600	.23	....	.....	70	

II.—*Effect of varying form of standard thickness.*

Mar. 9	169	Moffet copper (straight strips).	0.5 x .03	300	.015	....	.....		This was a straight strip, half an inch wide, and of standard length.
				350	.045				
				400	.075				
				450	.125				
				500	.205				
				550	.555	.332 x .024	.0079	53	
Mar. 9	170	....do	0.5 x .03	300	.01	....	.....		Same.
				350	.05				
				400	.075				
				450	.12				
				500	.195				
				550	.52	.333 x .024	.0078	52	
Means		....do	0.5 x .03	300	.0125	....	.....		See curve *g*, Plate VIII.
				350	.045				
				400	.075				
				450	.1225				
				500	.20				
				550	.5375	....	.....	52.5	

Abstract of record of mechanical tests—Appendix—Continued.

Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength.					Drop test.									Shearing.					Bending.		Remarks.
				Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	
1878. Mar. 9	171	Moffet copper (straight strips).	1.0 x .03	400	.005																				See curve *g*, Plate VIII; but one inch wide from same strip.
				500	.03																				
				600	.05																				
				700	.075																				
				800	.011																				
				900	.16																				
				1000	.25																				
				1100	.59	.768 x .023	.0176	59																	
Mar. 9	172	....do	1.0 x .03	400	.01																				Same.
				500	.025																				
				600	.055																				
				700	.08																				
				800	.12																				
				900	.165																				
				1000	.25																				
				1100	.60	.755 x .022	.0166	55																	
Means		....do	1.0 x .03	400	.0075																				See curve *h*, Plate VIII.
				500	.0275																				
				600	.0525																				
				700	.0775																				
				800	.115																				
				900	.1625																				
				1000	.25																				
				1100	.59			57																	
Mar. 7	161	Moffet copper (curved pieces).	0.5 x .03	300	.005																				To determine, if possible, whether it could be safely argued that resistances vary directly with the area of least resistance.
				400	.045																				
				450	.075																				
				500	.125																				
				550	.25	.406 x .024	.009	65																	

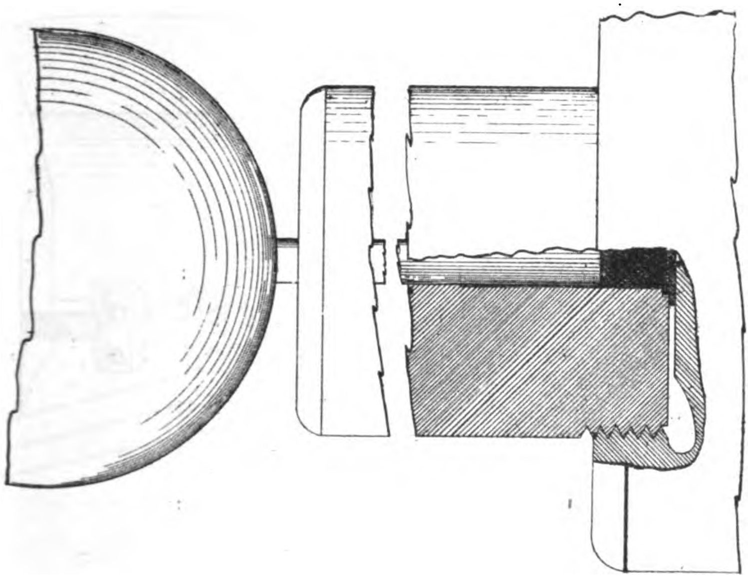
																									This gives a curve parallel to that of full section, but about 100 lbs. above it. See curve i, Plate VIII.
Mar. 9	175	do	.75 x .03	300	.005																				This was made from same strip as Nos. from 169. Its total width at ends was the same as 173 and 174. To see effect of varying least section with constant form of clip, see curve j, Plate VIII.
				400	.0075																				
				500	.02																				
				600	.055																				
				700	.10																				
				800	.19																				
				900	.30	.663 x .023	.0152	68																	
Mar. 9	173	do	1 x .03	500	.005																				Same as 171, but with widened ends; only 1".5 wide to compare effect of widening them as in standard specimen to 2".15.
				600	.02																				
				700	.045																				
				800	.07																				
				900	.10																				
				1000	.15																				
				1100	.25	.851 x .023	.0196	65																	
Mar. 9	174	do	1 x .03	500	.005																				Same.
				600	.02																				
				700	.045																				
				800	.065																				
				900	.10																				
				1000	.15																				
				1100	.30	.850 x .023	.0195	65																	
Means		do	1 x .03	500	.005																				See curve k, Plate VIII.
				600	.02																				
				700	.045																				
				800	.0675																				
				900	.10																				
				1000	.15																				
				1100	.275			65.75																	

Abstract of record of mechanical tests—Appendix—Continued.

III. *Effect of change of weight in shearing.*

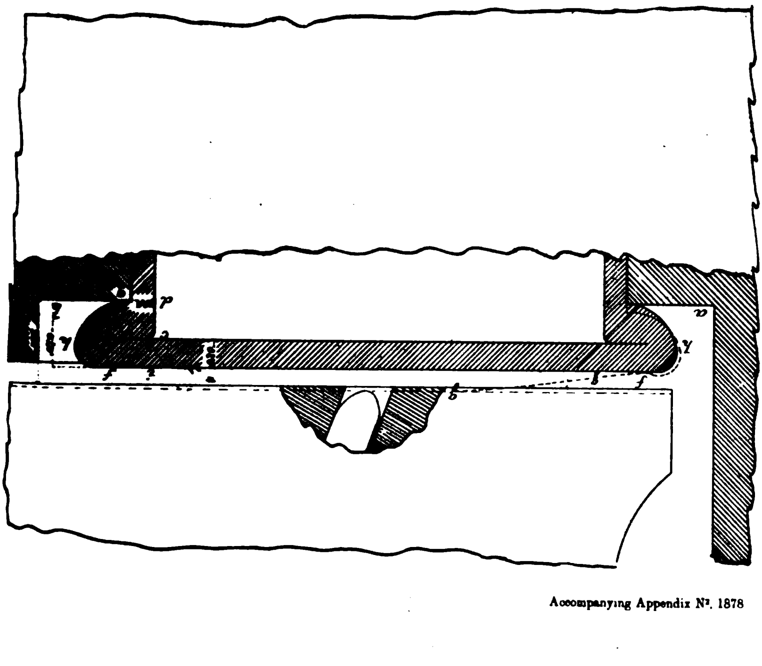
Date.	Laboratory number.	Material.	Dimensions on line of least resistance.	Tensile strength.					Drop test.									Shearing.					Bending.		Remarks.
				Strain in pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Total foot-pounds.	Extension of 1″.0.	Dimensions of fracture.	Area of fracture.	Reduced area, %.	Weight in pounds.	Number of blow.	Height in feet.	Foot-pounds of blow.	Effect.	Pressure.	Opening in degrees.	
1878. Apr. 8	200	Moffet copper....	1.57 x .030	....	....	....	....	....	....	..	....	....	....	....	....	....	..	3	1	1.26	3.78	through.	....	....	To try effect of changing weight in punching, see Nos. 85, 148, 152, 157.
Apr. 8	201	....do	1.57 x .030	....	....	....	....	....	....	..	....	....	....	....	....	....	..	7	1	.54	3.78	through.			
Apr. 8	202	....do	1.57 x .030	....	....	....	....	....	....	..	....	....	....	....	....	....	..	9	1	.42	3.78	through.			

Fig. 1.



Gill's éprouvette.

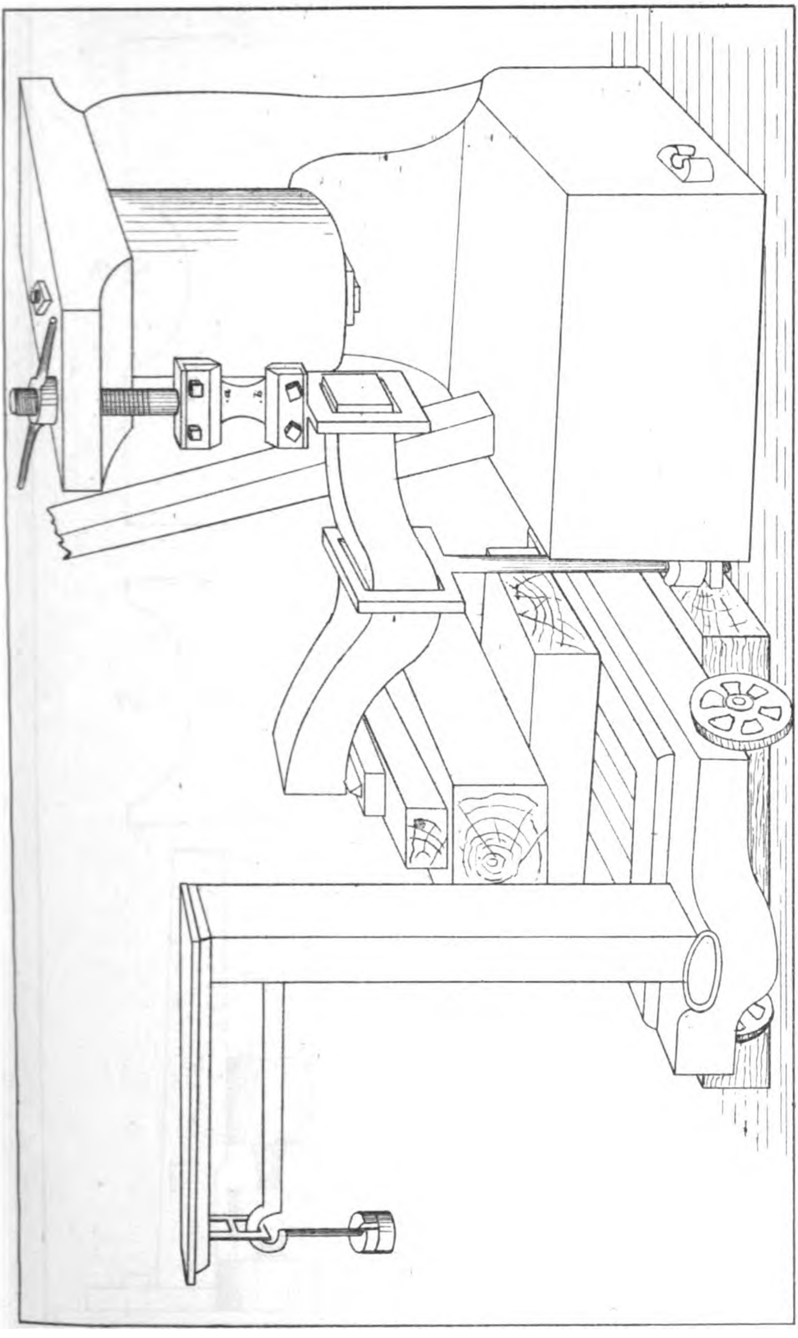
Fig. 2.



Section of cartridge head in chamber of gun.

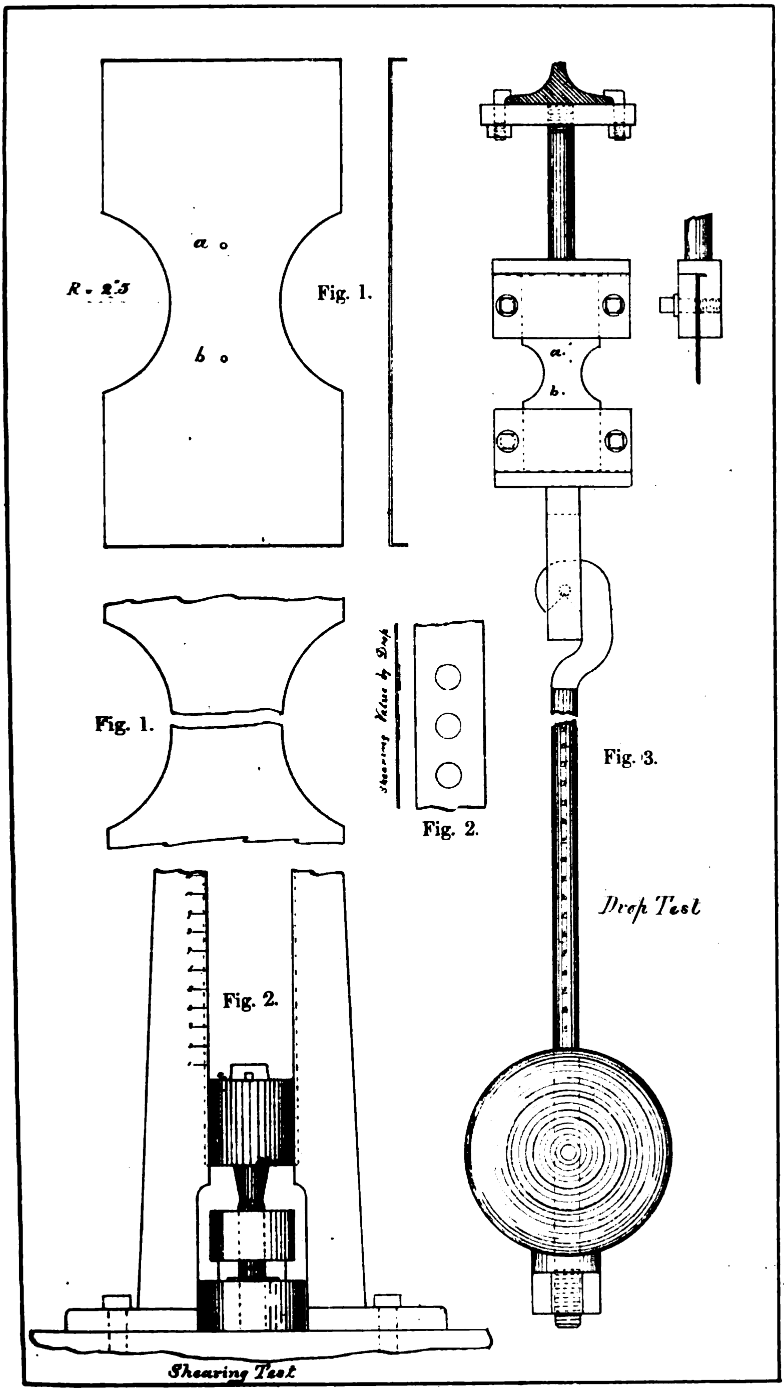
Accompanying Appendix No. 1878

PLATE II.



Improvised Testing Machine

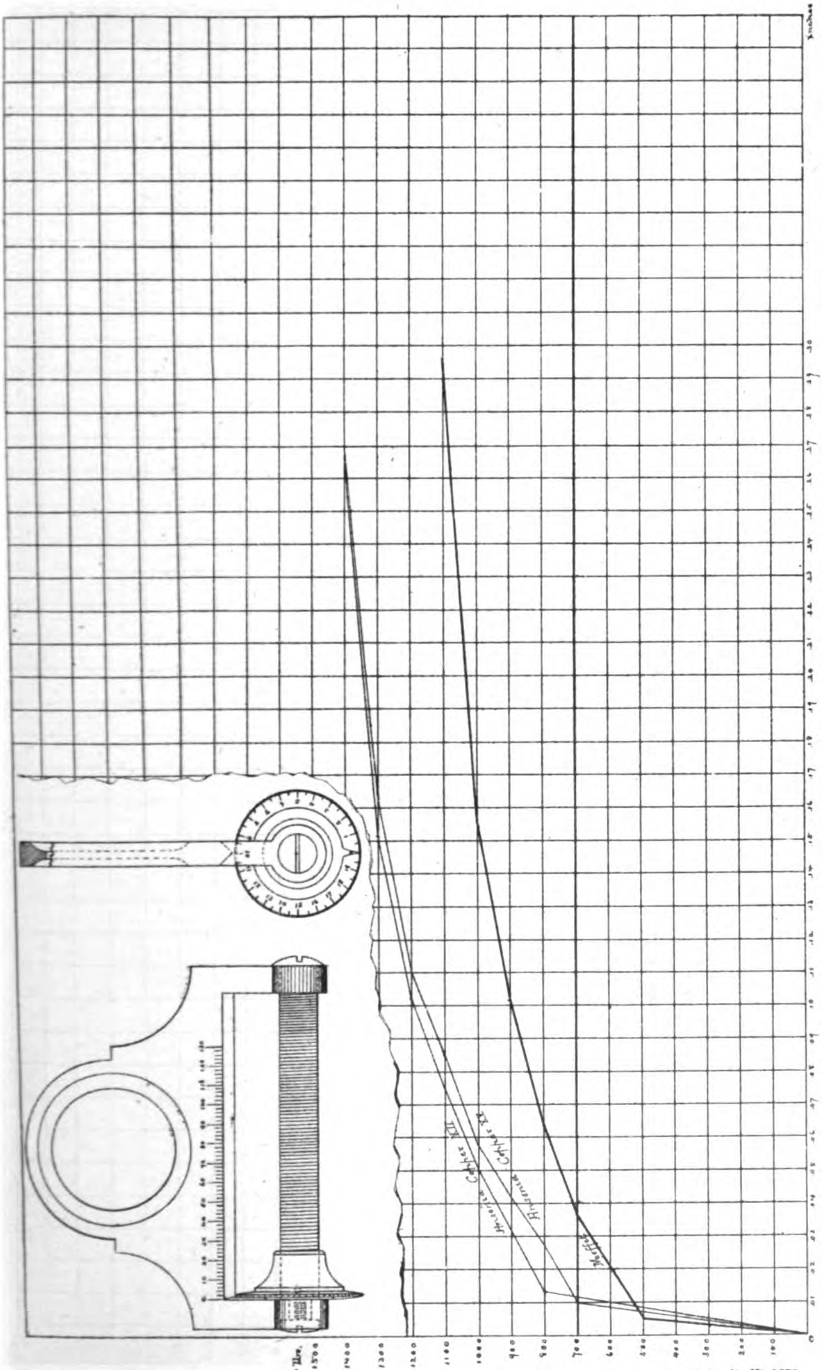
Accompanying Appendix N°. 1878



Accompanying Appendix No. 1878

Shearing and Drop Tests

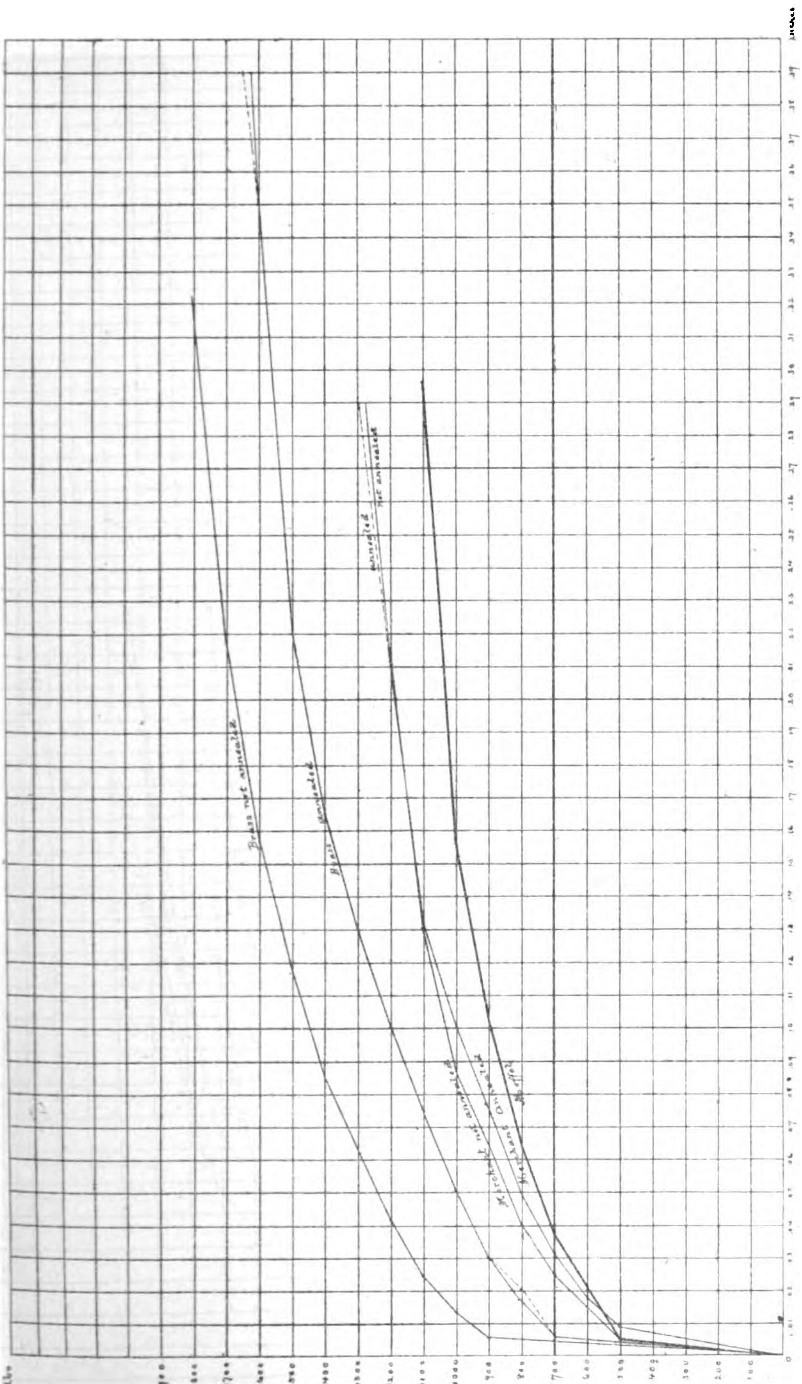
PLATE IV.



Ansonia XII and XV and Moffet — Measuring Wheel

Accompanying Appendix No, 1878

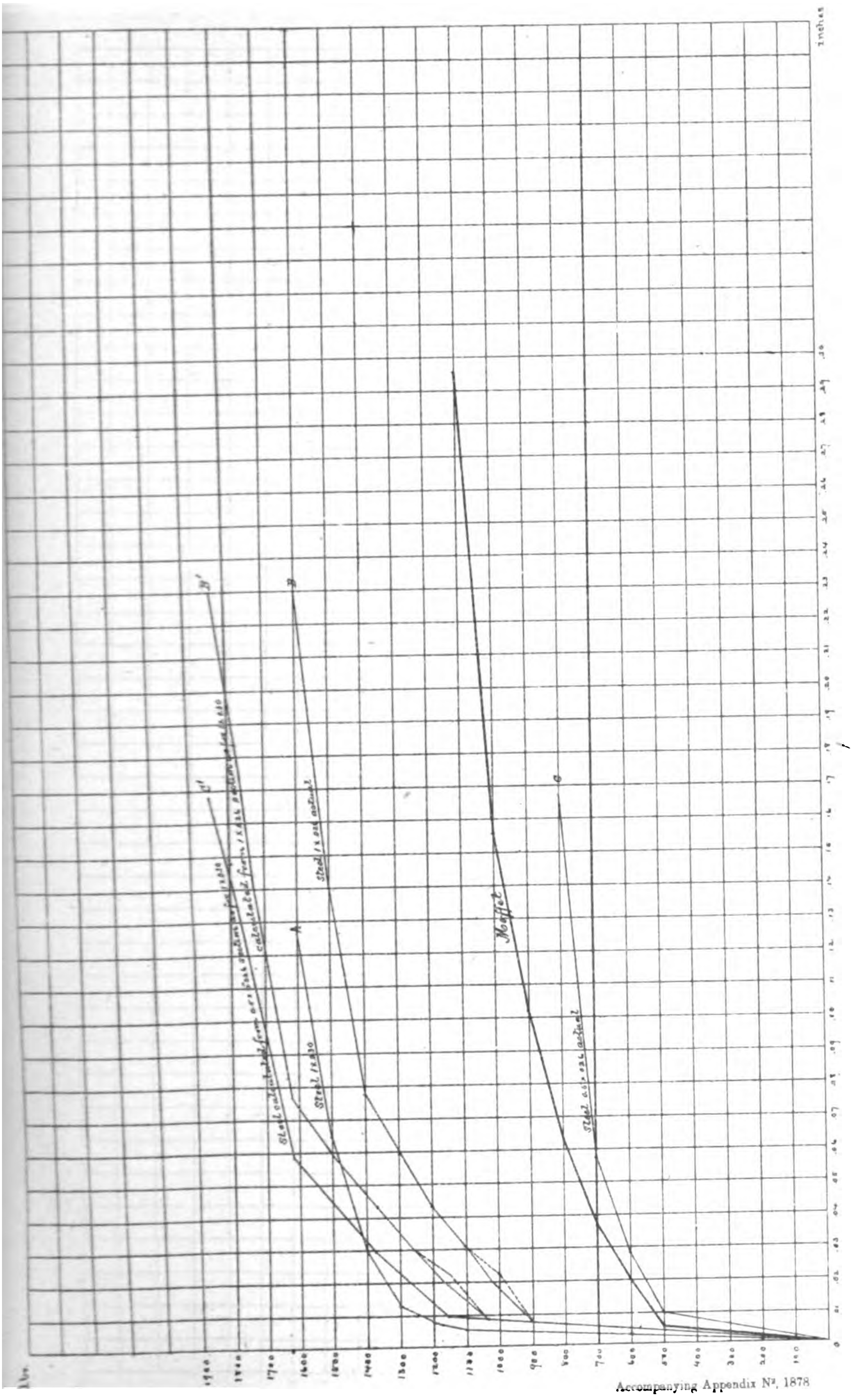
PLATE V.



Brass, Merchant and Moffet

Accompanying Appendix No. 1878

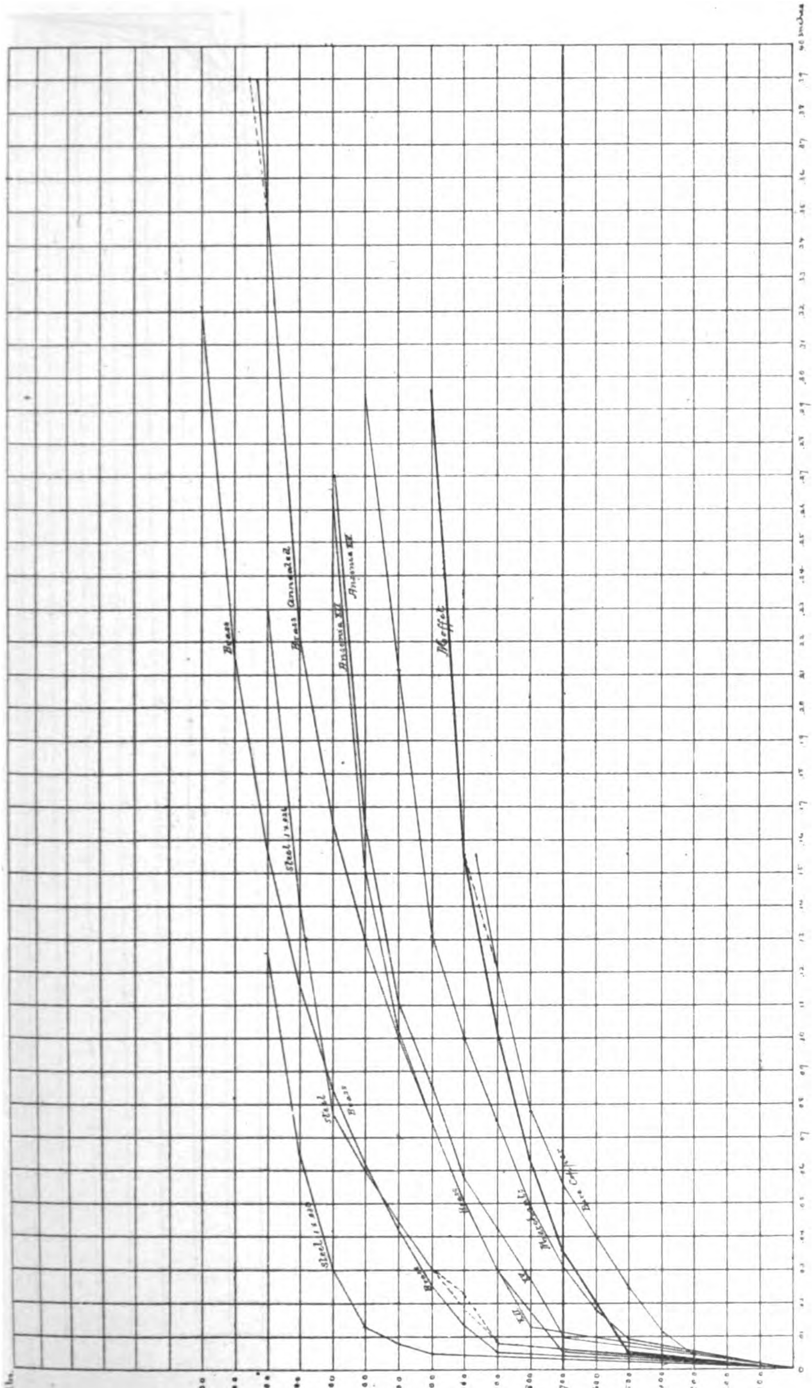
PLATE VI.



Steel and Moffat

Accompanying Appendix No. 1878

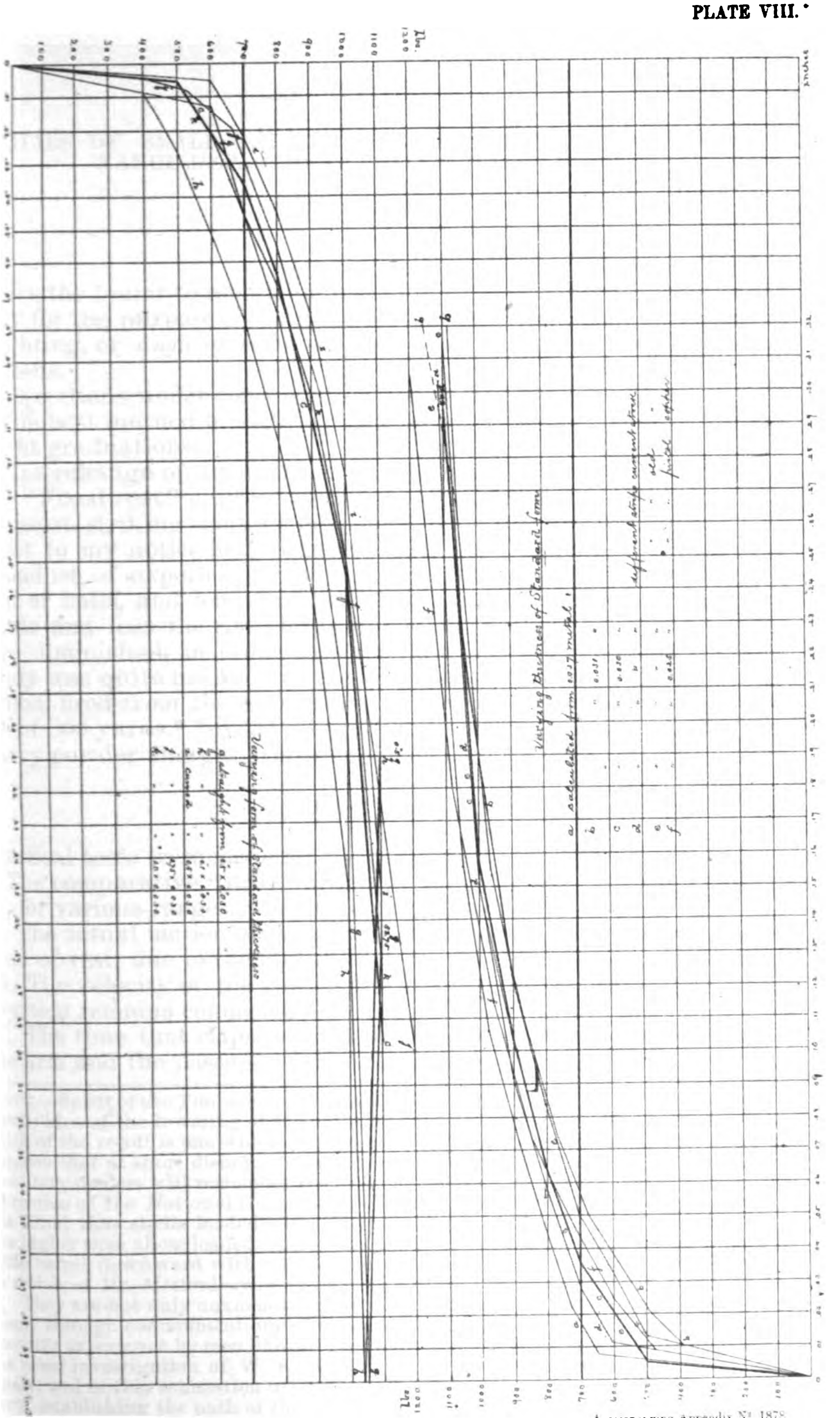
PLATE VII.



Accompanying Appendix No. 1878

All the Metals tested

PLATE VIII.



Accompanying Appendix No 1878.

Moffet Copper (Appendix)

APPENDIX O.

ANOMALIES OF SMALL-ARM PRACTICE. BY MAJ. J. P. FARLEY, ORDNANCE DEPARTMENT UNITED STATES ARMY.

(Three plates.)

NATIONAL ARMORY,
Springfield, Mass., January 18, 1876.

I have the honor to report the results of experiments conducted at the armory for the purpose of verifying and explaining certain variations in the sighting, or *angle of sight*, of small-arms when fired under different conditions.

The questions under consideration have a direct bearing upon—

I. The best method of sighting small-arms or establishing elevations for sight graduations.

II. Interchange of ammunition, as provided for the rifle and carbine.

III. "Fixed-rest" practice as compared with "off-hand" firing.

The most striking *anomaly* developed by this investigation was first brought to my notice in November, 1874, and in March, 1875, when, in the conduct of experiments for the determination of powder charges, weight of balls, and length of bore, it was found that for the range of 33 yards and less the rifle elevation had to be *decreased* as the powder charge diminished, in order to strike the small-velocity target. This anomaly was quite marked for the interchange of rifle and carbine ammunition, fired from the *carbine*, and it developed in this arm up to the range of 300 yards,* beyond which the greater remaining velocity due to heavy powder charges overcame the anomalous practice.

THE TRIAL.

Practical tests were made for the purpose of ascertaining—

I. The comparative "drop" or fall of the rifle and carbine cartridge balls, for various ranges, when fired from the carbine and the rifle.

II. The actual motion of the muzzle of the carbine when it starts from a state of rest, due to the *disturbing influence* of the force of discharge.

III. The velocity of the ball in the bore of the carbine and the time the system remains connected.

IV. The time that elapses between the first movement of the muzzle of the arm and the passage of the ball from the bore.

*NOTE.—Spirit of the Times, New York, April 13, 1878.—[Editorial Extract.]—" * * * Metford's idea of the lowering of the elevation through the springing of the rifle from the kick of the recoil is one which has been before referred to in the Spirit. It is for this reason that at short distances small charges so often shoot higher than large ones. Our military readers will remember the astonishment which was created in the armory rifle practice of the National Guard of the State of New York a year or so ago, when it was found that shells loaded with thirty-five grains of powder, at 150 feet, shot 6 inches higher than those loaded with seventy grains. This arose from this springing of the rifle barrel downward with the heavier charge. It is to be hoped that this elaborate article of Mr. Metford's will meet with a cordial reception from American riflemen. They are not only anxious to shoot well, but "to know the reason why"; and it is only through communications of this description, embodying the results of years of scientific experience by men like Mr. Metford, that that knowledge can be acquired."

The recent investigation of W. E. Metford, C. E., assigns a practical value to this anomaly, and in this connection attention is invited to the date of experiments at the armory, establishing the path of the muzzle of small-arms under the force of discharge and during the time of passage of the ball through the bore.

V. The relation of the different parts of the system and forces acting, both before and at the instant of discharge.

GENERAL DESCRIPTION OF ARMS.

Carbine, models 1873; weight, 7 pounds; total length of barrel, 22 inches.

Globe and peep-sight for 300 and 500 yards.

Rifle, model 1873; weight, without bayonet, 8½ pounds; total length of barrel, 32.6 inches.

Globe and peep-sight for 300 and 500 yards.

GENERAL DESCRIPTION OF AMMUNITION.

The carbine-cartridge, 55 grains powder, 405 grains ball.

The rifle-cartridge, 70 grains powder, 405 grains ball.

Velocity of carbine-ball from carbine, 1,080 feet. Recoil, 155 pounds.

Velocity of carbine-ball from rifle, 1,107 feet. Recoil, 142 pounds.

Velocity of rifle-ball from carbine, 1,210 feet. Recoil, 182 pounds.

Velocity of rifle-ball from rifle, 1,320 feet. Recoil, 174 pounds.

This is the *ratio* of velocities that generally obtains, and the comparative measures of recoil on spiral spring.

MODE OF CONDUCTING TARGET PRACTICE.

The firing was done under my personal supervision by the principal marksman of the armory. The target records were all made for the various ranges by firing 40 shots, 20 of each kind of ammunition *alternately*, under precisely the same conditions from the same arm. The ranges of 300 and 500 yards demanding greater steadiness than "off-hand" practice afforded, firing from the shoulder, with an elbow rest and with the muzzle lightly resting on an *elastic* support, was resorted to for these ranges, and the aim was taken through the globe and peep-sight for all the ranges.

TABLE NO. 1.—*Carbine.*

TABULATED RESULTS OF TARGET-PRACTICE.

33 yards.			33 yards.			100 yards.			100 yards.			300 yards.			300 yards.			500 yards.		
No. shots.	Off-hand, vert.		No. shots.	Off-hand, vert.		No. shots.	Off-hand, vert.		No. shots.	Off-hand, Elbow rest.		No. shots.	Elbow rest.		No. shots.	Elbow rest.		No. shots.	Elbow rest.	
Alternate.	A.	B.	Alternate.	A.	B.	Alternate.	A.	B.	Alternate.	A.	B.	Alternate.	A.	B.	Alternate.	A.	B.	Alternate.	A.	B.
C. C. 20	......	4.65	20	......	4.37	20	1.9	......	20	......	1.47	20	4.35	......	20	......	.9	20	......	14.6
R. C. 20	......	5.71	20	......	6.67	20	......	2.25	20	......	4.65	20	......	2.45	20	......	6.8	20	10.5	......
																			No an	omaly

TABLE NO. 2.—*Rifle.*

33 yards.			100 yards.			300 yards.			500 yards.		
No. shots.	Off-hand, vert.		No. shots.	Off-hand, vert.		No. shots.	Elbow rest.		No. shots.	Elbow rest.	
Alternate.	A.	B.	Alternate.	A.	B.	Alternate.	A.	B.	Alternate.	A.	B.
C. C. 20	......	.9	20	......	4.10	20	......	13.45	20	......	41.4
R. C. 20	......	......	20	......	......	20	......	.5	20	9.1	......

Table No. 1 and target diagrams, Plate I, show an anomalous effect, due to difference in powder charges (70 and 55 grains) in the carbine practice, within range limits of 300 yards, the *center of impact* of the ball having an initial velocity of 1,080′, being above that for the same ball having an initial velocity of 1,210′, the arm being fired in the manner before specified.

Table No. 2 exhibits the rifle practice without anomaly; the ball having an initial velocity of 1,320′, keeping above the same ball with an initial velocity of 1,107′, as it should, under the condition of the *angle of departure* and *angle of sight* or *elevation* being the same. For very marked difference in powder charges the anomaly develops as well for the rifle as for the carbine, but does not hold for ranges greater than 100 yards.

MOTION OF BARREL.

To ascertain if there is motion in the arm at the instant of discharge, which would be likely to produce the effect noted in target practice, a carbine was held as shown at Fig. 1, Plate III.

The sight in front with the blackened point of the hook being placed in direct contact with a vertical screen, S, the carbine, when fired, left a black dot on the screen, indicating the original point of contact of the hook. Slightly inclining the screen, to catch any downward motion of the muzzle (which was anticipated to accord with the practice), the carbine when again fired left upon the screen a well-defined line, starting from the original point of contact of the hook and running down along the screen until the motion of the arm to the rear exceeded the downward motion of the muzzle. Inclining the screen more nearly horizontal, the carbine was a third time fired, and the hook point recorded a longer line. After this, the screen was inclined so as to catch any upward motion of the muzzle, and the carbine fired, but in this case the hook did not rise or touch the screen until the arm had moved an inch or more to the rear.

With points established by this method the full-size curves or paths described by the muzzle of the carbine are shown at A, B, and C, Fig. 2, Plate III, A being the path when 70 grains powder charge was fired, and B and C the paths due to 55 and 20 grains, respectively.

In order to confirm the method of tracing the path of the muzzle, a pointer was attached to it and brought up against a vertical screen parallel to the plane of fire or plane of recoil, and the pointer described the curves indicated in Fig. 3, Plate III, R R′ R″ R‴, for the rifle-cartridge, and C for the carbine-cartridge. Having ascertained that there is an actual motion of the barrel, more or less marked in proportion to powder charge, and in harmony with the target practice, it is next in order to determine—

THE VELOCITY OF BALL IN THE BORE.

The space is 19 inches, and, knowing the velocity sought, the motion of the system may be computed and the time ascertained during which the system remains connected. Knowing the time between the ignition of powder charge and the first downward tendency to motion of the muzzle, the position of the ball may be determined when the "dip" is well developed.

The "Le Boulengé Micro-Chronometer" has been used to record the required times, and the rifle in place of carbine, as offering a greater length of bore on which to base the experiment.

A wire passing a little in front of the ball at its seat, and another across the muzzle, constituted the first and second targets. The rifle, with rifle-cartridge, was then fired and the times recorded for four shots, noted in Table 3.

TABLE No. 3.—*Time of passage of ball from seat of charge to muzzle of rifle.*

Number of shots.	Time.	Velocity per second.
	"	*Feet.*
1	0.00343	732
2	.00216	1,157
3	.00285	877
4	.00259	965
Mean....	.00275	932

The practical method of measuring an interval of time so minute as 0".00275 may be attended with instrumental errors, therefore the results are, at *your suggestion*, verified in the following manner:

Ordnance Notes No. XXXVIII gives the velocities for various lengths of barrel, including length of chamber:

5" length, 704' initial velocity.
12" length, 1,100' initial velocity.
22" length, 1,210' initial velocity.
26" length, 1,254' initial velocity.
32".6 length, 1,320' initial velocity.,

If the resistance to powder charge be *constant*, the *quantity of work* performed would be measured by the product of the resistance into the path described by its point of application. In other words, the motion of the ball being uniformly accelerated, its mean rate of velocity per second through the bore comes from the relation

$$\frac{0' + 1320'}{2} = 610$$

The resistance being *variable* for different lengths of bore (as before shown), the *velocity* is estimated by taking the sum of the elementary times and quantities of work. By this method we have from the relation established—

$\frac{1254' + 1320'}{2}$ = velocity for first fraction of path (6".6 or '.55) = 1287',

$$t = \frac{S}{V}, t = \frac{'.55}{1287'}, = ''.000435;$$

$\frac{1210' + 1254'}{2}$ = velocity for second fraction of path (4" or '.33) = 1232',

$$t^a = \frac{'.33}{1232'}, = ''.000268;$$

$\frac{1210' + 1100'}{2}$ = velocity for third fraction of path (10" or '.83) = 1155',

$$t^b = \frac{'.83}{1155'}, = ''.000717;$$

$\frac{1100' + 704'}{2}$ = velocity for fourth fraction of path (7" or '.58) = 902',

$$t^c = \frac{'.58}{902'}, = ''.000643;$$

$\frac{704' + 0'}{2}$ = velocity for fifth fraction of path (1''.44 or '.12) = 352',

$$t^{d} = \frac{352'}{'.12}, = ''.000340.$$

$T = t + t^{a} + t^{b} + t^{c} + t^{d}$.
T = (''.000435 + ''.000268 + ''.000717 + ''.000643 + ''.000340 = ''.002403.
S = 2'.424 = space.)

$V = \frac{S}{T} = \frac{2'.424}{''.002403} = 1087'.$

(Equation 7, "Bartlett's Mechanics.") $Q = \int P\, ds.$

Q, the quantity of work, is equal to the area included between the path s, in direction of resistance, the curve whose ordinates are the different values of P, and the ordinates which denote the extreme resistances. As the equation for the curve which connects the resistance with the path in the special case under consideration is not known, the work cannot be estimated by simple integration, but the estimate is made in the manner prescribed ("Bartlett's Mechanics," equation 10):

$$Q = \tfrac{1}{3}\, e_1 e_2\, [e_1 r_1 + 4 e_2 r_2 + 2 e_3 r_3 + 4 e_4 r_4 + 2 e_5 r_5 + 4 e_6 r_6 + e_7 r_7].$$

In equation (10) Q = quantity of work for a length of barrel over which velocity of ball is measured.

$$= ('.404 \times 6) = (2'.424)$$

$$\left.\begin{array}{l} e_1 e_2 = '.404 \\ e_1 r_1 = 0 \end{array}\right\} \left.\begin{array}{l} e_2 r_2 = 817' \\ e_3 r_3 = 1100' \end{array}\right\} \left.\begin{array}{l} e_4 r_4 = 1155' \\ e_5 r_5 = 1210' \end{array}\right\} \begin{array}{l} e_6 r_6 = 1265'; \\ e_7 r_7 = 1320'; \end{array}$$

$$Q = .1345\, [0 + 3268 + 2200 + 4620 + 2420 + 5060 + 1320];$$
$$Q = 2540;$$

$\frac{Q}{2'.424} = 1047'.$

Velocity of rifle ball in rifle by experiment	932'
Velocity of rifle ball in rifle by sum of times	1087'
Velocity of rifle ball in rifle by quantity of work	1047'
Mean velocity	1022'

Correct for carbine length.

$$V = \frac{1.536}{''.0017} = 904';$$

904' = velocity rate of ball in passing through bore of carbine.

From the foregoing calculations and experiments it is found that the velocity of the rifle cartridge ball through the bore of the carbine is at the rate of 904 feet per second, and the time of passage through the bore is ''.0017.

To obtain the quantity of motion of the carbine due to 904 feet for the ball, substitute in equation (1) values for $m\ v$ and M—

$V = \frac{m\, v}{M} (1)$ $\qquad V = \frac{\frac{405}{g} \times 904}{\frac{49000}{g}}$

$m = \frac{405}{g}$ grs. $\qquad V = 7'.47$

$v = 904'$

$M = \frac{7 \text{ lbs. or } 49000 \text{ grs.}}{g \qquad\qquad g}$ $\qquad V = 89''.64.$

As the carbine moves to the rear (89″.64) inches per second, therefore during the time (″.0017) that the ball remains in the bore the arm should pass over an interval of fifteen hundredths of an inch.

In this time, as shown by the curves, Fig. 4, the muzzle has fallen in a more rapid ratio than it has receded; therefore, theoretically, the dip of the muzzle has exceeded fifteen hundredths of an inch as the ball leaves the bore.

PRACTICALLY TO DETERMINE IF BALL IS IN BORE DURING MOTION OF BARREL.

The "Le Boulengé Micro-Chronometer" has been used to measure the interval between the first downward motion and the passage of the ball from the muzzle. It was not known whether the result would be recorded positively or negatively on the instrument, since the resistance due to the inertia of the mass of the carbine might give negative readings, or show that the ball actually did get away before the motion was communicated to the arm. To ascertain this point, the hook of the carbine in the circuit of one target was placed against a copper plate (also in the same circuit), made fast to the screen, and was so adjusted as to necessitate a downward motion of ″.05 before the circuit should be broken. A wire stretched across the muzzle carried the circuit of the other target.

Four shots were fired with the carbine adjusted as stated, with the following records or intervals of time between the ″.05 motion of the barrel and the passage of the ball from the muzzle:

No. 1	″.000259
No. 2	″.000389
No. 3	″.000390
No. 4	″.000584
Mean	″.000405

This places the ball at a distance from the muzzle (in the bore) when it (the muzzle) has fallen ″.05 (inch), and practice accords with theory.

RELATION OF FORCES. (See Fig. 3.)

The center of inertia of the arm is at G; the left hand (at B) and arm of the marksman support a weight of 5 pounds, and the shoulder (at R) a weight of 2 pounds, more or less. When the right hand is placed in a position at A, there is an additional weight of 2 pounds added to the weight of the arm, and the center of inertia is thereby shifted to same point G′.

The direct action of the force of discharge *should* impart upward motion about the center of inertia, and afterward cause this point (at G′) to move in a direction opposite to the motion of the ball, which when met by resistance, as the arm is well set up at the shoulder R, the motion of rotation is further developed. The path of the muzzle of the carbine *after* the lapse of seventeen ten-thousandths of a second of time is to the rear and upward, as is to be expected; but it is shown by these experiments that during the minute interval in which the ball remains in the bore the muzzle actually dips its line of fire, and this in a direct ratio with increase of powder charge. In other words, the equilibrium maintained before discharge is destroyed at the instant of ignition of powder charge. The only forces acting before the piece is fired are those of *gravity* and *resistance to gravity;* but when fired undoubtedly there is

a resultant effect, due to the operation of several forces at the moment of discharge, which accounts for the departure of the muzzle from the path determined for it, when the single force of reaction or recoil is alone considered.

Under the ordinary conditions of practice the anomaly (which is verified by these experiments) does not appear, for the reason that the sight graduation for a *special ammunition* has been verified and adjusted to compensate practical errors. The moment, however, there is a departure from the conditions specified for the ammunition or for the manner of firing the arm, not only do marked variations appear in the practice, but variations as anomalous as unexpected.

That a ball having an initial velocity of but 1,080 should strike higher than the same ball with an initial velocity of 1,210 feet, fired alternately, under identical circumstances, is certainly surprising. The neutral point beyond which the anomaly ceases is the one where the greater remaining velocity begins to tell *in favor* of the ball having the greatest initial velocity.

In this connection we are brought to consider the effect of

THE FIXED REST.

When an arm is fired under perfect conditions, as in the "fixed rest," practical sight-corrections that have been made appear as errors. On page 180, Ordnance Notes XXIX, Vol. I, I find stated in your report on "Muzzle-rifling":

> In the foregoing firings, which were all made from the fixed rest, the aim for 300 yards was taken through the 100-yard sight; that for 500 yards was taken through the 300-yard sight. This diminution of elevation comes from the fact that the gun was firmly attached to the slide of the fixed rest; but whether it was owing to the manner the gun was fastened to the slide or to the diminished recoil, from weight of slide, at the moment of firing, is not precisely known.

To confirm and as far as possible explain these results, a carbine was placed in a "fixed rest" and fired 40 shots and off-hand 80 shots. (See Table No. 4.) Again using a line of sight parallel to axis of bore, and correcting for fall due to gravity ($h=\frac{1}{2}gt^2$), Tables Nos. 5 and 6, results from the target-practice.

TABLE No. 4.—*Comparative practice "off-hand" and "fixed rest," 33 yards.*

No. of shots, alternate.	Fixed rest.		No. of shots, alternate.	Off-hand.		No. of shots, alternate.	Off-hand.	
	Above.	Below.		Above.	Below.		Above.	Below.
R. C. 20	....	3''.64	R. C. 20	....	5''.71	R. C. 20	....	6''.67
C. C. 20	....	3''.62	C. C. 20	....	4''.65	C. C. 20	....	4''.37

TABLE No. 5.—*Same as Table No. 4, angle of sight eliminated.*

No. of shots.	Fixed rest.		No. of shots.	Off-hand.		No. of shots.	Elbow rest.		33 yards.
	Above.	Below.		Above.	Below.		Above.	Below.	Corrected for—
R. C. 20 ..	....	5''.8	R. C. 20	....	10''.74	R. C. 20	....	9''.72	$h=\frac{1}{2}gt^2$ and height
Corrected.	....	0.0	....	....	4''.94	....	....	3''.92	of sight-line.

TABLE No. 6.—*Rifle fired same as Table No. 5, 33 yards.*

No. of shots.	Fixed rest.		No. of shots.	Off-hand.		No. of shots.	Off-hand.	
	Above.	Below.		Above.	Below.		Above.	Below.
R. C. 30	0	0	R. C. 20	....	7''.0	C. C. 20	....	7''.44

From what is shown respecting the motion of the muzzle in the usual mode of firing, it is reasonable to conclude that whatever difference there may be between off-hand and fixed-rest practice is owing to a greater exactness of the latter method as compared with the former. The conditions of unnatural constraint in the fixed rest should forbid its employment as a means of establishing standards of reference for general-service practice; and although it answers well the requirements of exact experiments and close investigations, yet beyond this it serves no practical purpose.

NOTE.—MAY, 1878. My report of February 26, 1876, shows a comparison of the off-hand or natural *angle of elevation*, the fixed-rest *angle of departure*, and the *angle of departure* theoretically computed by Didion's method for spherical projectiles, modified by the value of A for the ''.45 caliber-service bullet. In order to present at this time a very exact comparison of these angles, rifle No. 84852 has been selected at random from the daily manufacture at the armory, and its sight carefully verified by the foreman:

φ = angle of sight graduation for 500 yards.

φ^1 = angle of sight graduation for 300 yards.

$$\text{Sin. } \varphi = \frac{1''.175 - ''.60}{25''.23} = \frac{''.575}{25''.23} = ''.02279.$$

$\varphi = 1^\circ\ 18''\ 13''$ when very fine sight is drawn.

$$\text{Sin. } \varphi^1 = \frac{''.93 - ''.60}{25''.18} = \frac{''.33}{25''.18} = ''.0131,$$

$\varphi^1 = 0^\circ\ 45'\ 20''$ when very fine sight is drawn.

The targets marked 1, 2, and 3, Plate II, were then made by a skillful marksman with the rifle and rifle-cartridge. The 500 yards sight-scale elevation ($1^\circ\ 18'\ 3''$) was employed for the targets Nos. 1 and 2, and the sight-scale elevation ($0^\circ\ 45'\ 20''$) for the target No. 3 (fixed rest).

The angle of correction φ'' to be applied to the target No. 3, or fixed-rest practice, in order to bring its *center of impact* up to the point sighted, comes from the relation $\tan. \varphi'' = \frac{9'}{1500} = .00600,$

$$\varphi'' = 0^\circ\ 21'\ 0'.$$

Applying this correction, and we have (500 yards range):

With fixed rest, *angle of departure*, $1^\circ\ 6'\ 20''$.

With off-hand or elbow rest, *angle of elevation*, $1^\circ\ 18'\ 3''$.

To find the angle of departure by Helie ("Traité de Balistique") for *oblong* projectiles with ogival heads, we have:

$\frac{\text{Sin. } 2a}{gx} = \frac{1}{v^2} + \frac{kx}{v}$, in which k depends for its value upon a numerical coefficient 0.000063, and which increases with the shortness of the radius with which the ogival is struck. This number is assumed to be correct for the ''.45 caliber service ball.

x = range; in this case 500 yards = 1,500 feet.

v = initial velocity; in this case 1,340 feet, same as for the target-practice.

$k = \frac{3e}{4} = 0.0000472 \frac{R^2}{W}$.

$e = 0.000063 \frac{R^2}{W}$.

$R = \frac{''.45}{2} = '.0187$ = radius bullet.

W = 405 grains = 0.057 pounds, weight bullet.

g = force of gravity = 32.155 feet; its log. = 1.507248.

For convenience, in order to avoid the use of very small numbers, multiply both sides of the equation by 10^{10}, and it becomes

$$\frac{10^{10} \sin. 2a}{g x} = \frac{10^{10}}{v^2} + \frac{10^{10} k x}{v}.$$

Solving the equation with reference to value of a, the elevation sought, and substituting

$\log. R^2 = \bar{4}.543684$

$\log. W = \bar{2}.761928$

$\log. \frac{R^2}{W} = \bar{3}.781756$

$\log. .00004725 = \bar{5}.674402$

$\log. k = \bar{7}.456158$

$\log. g = 1.507248$

$\log. x = 3.176091$

$\log. g x = 4.683339$

$\log. 10^{10}k = 3.456158$

$\log. x = 3.176091$

$\log. 10^{10}k x = 6.632249$ and $\log. 10^{10} = 10.000000$

$\log. v = 3.127104$ and $\log. v^2 = 6.254208$

$\log. \frac{10^{10}k x}{v} = 3.505145$ and $\log. \frac{10^{10}}{v^2} = 3.745792$

$\frac{10^{10}k x}{v} = 3199.9$

$\frac{10^{10}}{v^2} = 5569.2$

8769.1

$\log. 8769.1 = 3.9429506$

$\log. g x = 4.6833390$

$\log. (8770.8) g x = 8.6262896 = \log. 10^{10} \sin. 2a$

$2a = 2^\circ\ 25'\ 30''$

$a = 1^\circ\ 12'\ 45''$.

From the foregoing computations and target practice it is shown—

1. That the elevation to be given by the marksman is the one established on the sight scale:

For 500 yards range it is 1° 18′ 3″.

2. That the elevation to be given for the "fixed rest" is something *less* than on the sight scale:

For 500 yards range it is 1° 6′ 20″.

3. That the theoretical approximate *angle of departure* is something between the natural angle of elevation and the fixed-rest angle of elevation:

By Hélie, for 500 yards range it is 1° 12′ 45″.

In this instance the *angle of departure* theoretically computed for the ogival head, oblong projectile, is a mean of the angles of elevation practically applied for "off-hand" and "fixed-rest" firing. It does not follow, however, that the same relation will hold for *all* ranges or by other methods of computation, but enough is shown to indicate that for a service arm, intended to be used by the soldier, all refined methods of

theory and the "fixed rest" must give way to practical tests for the regulation and adjustment of the sight scale.

Arm No. 84852, taken at random from the daily manufacture at the armory, by its performance fairly illustrates the correctness of method adopted in regulating its sight scale. The score made by the marksman (see target No. 2) was 47, out of a possible 50 points, at a range of 500 yards. No correction of any kind was made on the elevation called for by the sight scale for this range, but precaution was taken, for the sake of comparison, to draw a fine sight. Had the theoretical *angle of departure* been applied on the sight scale, the *center of impact* would have fallen 2′.5 below the object sighted, and had the fixed-rest angle been applied, the *center of impact* would have fallen 5′ below the same object (see target No. 5).

ARM IN FIXED REST PARTIALLY LOCKED.

In regard to the fixed-rest system, as it has to do with the arm not being *firmly locked*, reference to the extract from your report shows that "partial experiments were made at this armory some time ago, by Brevet Captain Stockton, to obtain the explanation for this and some other peculiarities in firing arising from the particular way a rifle is held when discharged. I hope soon to be able to complete these experiments and forward a report of them for the information of the Department." The following is taken in full from the Armory Journal Record, February 10, 1871: "Experimented with an S. R. M. in different situations" (see accompanying target records, table No. 7). "Contrary to expectation, it was found that when the gun was clamped in front of the center of gravity the shots were higher than when clamped in rear of that point; the gun was next fastened to a wheel, so as to admit of the whole rotating evenly." This is all that is contained in the record or on file at the armory. In June, 1871, however, the following experiment is recorded by Captain Stockton:

Arranged a regulation barrel to try whether it springs before the bullet leaves the muzzle:

The breech was securely clamped in a vise, an adjustable piece of metal was placed 0″.01 above the muzzle. To this piece a wire was fastened, which was then passed over a cleat and stretched directly across the muzzle of the gun and one inch from it; the wire then led to the Ruhmkorff coil. The wire from the battery was connected with the barrel.

By this means a spark was thrown whenever the barrel was brought in contact with the piece of metal over the muzzle, so that if, on discharging the gun, a vibration of 0″.01 obtains before the bullet leaves the muzzle, a spark will be thrown; but as the wire in front is cut by the bullet and the connection destroyed, a subsequent vibration will not have any effect. This arrangement was tried several times, and the piece of metal was placed to the side of and under the muzzle.

No spark was thrown. The distance of 0″.01 was then reduced to 0″.076, but with the same result. This experiment seems, therefore, to prove that there is no vibration of the barrel as great as 0″.075 before the ball leaves the bore.

TABLE No. 7.—*Arm used in* 1871, *trial S. B. M.*, 1868 *model; arm used in present trial, carbine*, 1873 *model; range for Captain Stockton's results*, 200 *yards*; *present trial*, 30 *yards*.

Rifle, 1868, held.	No. of shots.	Vertical deviation.		Carbine, 1873, held.	No. of shots.	Vertical deviation.	
		Above.	Below.			Above.	Below.
Upper band	5	....	3″.48	....	....	....	....
Lower band (in front of C. G).	5	6″.24	....	In front of C. G	5	2″.3	....
Butt	5	....	4	In rear of C. G	5	....	8″.6
Fixed rest	5	0	0	Both front and rear	25	....	0
Off-hand	5	....	29	....	25	....	6″.19

The explanation sought in 1871 for the anomalous results noted in Table No. 7 may be *inferred* from the experiment to ascertain if there was any spring or vibration in the barrel; but this theory was not at that time sustained, since, under the special circumstances of constraint in which the barrel was held in a vise at its rear end, there was found to be no vibration so great as ″.0075 before the ball left the bore.

This experiment, with the barrel locked or constrained at its rear end, was calculated to discover any *wave* or *vibratory motion* along the barrel length, as such an effect was suspected years ago at the armory. The failure of the experiment to record any such motion was probably due to the resultant action of all forces developed being coincident with the axis of bore. The results of "off-hand" carbine practice enumerated in this report, and the paths described by the muzzle (curves Fig. 2, Plate III) of carbine at instant of discharge, all point to a disturbance of the line of fire before the ball leaves the bore. A *dip* of muzzle is plainly indicated, and this is developed to a greater or less extent in proportion to powder charge or force generated.

In order to ascertain if *gravity* had to do with the downward motion of muzzle at that moment when the left arm of marksman might be disturbed in its support by the shock of discharge, a carbine was arranged with a rigid rod underlying the lowest element of the barrel, but separated from the barrel by an adjustable interval. The rod being firmly connected with the stock was constrained to partake of all motion communicated to the carbine with the exception of a *spring* or *buckling* of the barrel itself. In firing the carbine naturally from the shoulder with its own cartridge (55 grs. powder), an interval as great as ″.15 was not closed between the rod and the lowest element of the barrel at the muzzle. When the rifle cartridge, however, was employed the interval closed fully, as was indicated by the paint on the rod being left on the under surface of the barrel at the muzzle. This experiment plainly indicates a spring or buckling of barrel muzzle toward the lowest side of the arm, and while this is the probable cause of the anomalous results in this trial, it is not improbable that the equilibrium between *gravity* and *resistance* to *gravity* (shown at Fig. 1, Plate III) may likewise be disturbed by shock of discharge and assist the dip.

RECAPITULATION.

I. Target practice with the rifle, and especially with the carbine, indicates greater drop of the *center of impact* for a ball having high velocity than for the same ball having low velocity; the anomaly holding for moderate ranges with the rifle, and up to 300 yards with the carbine.

II. There is an actual downward motion of the muzzle of the rifle and carbine at the instant of discharge. This is accompanied by a rear motion, and afterward followed by an upward rotary motion about the point of resistance at the shoulder.

III. The velocity of the rifle cartridge ball in the bore of the carbine is at the rate of 904 feet per second, as against an initial velocity from the bore of 1,210 feet; the interval of time (due to this velocity) in which the system remains corrected is the seventeen ten-thousandths of a second.

IV. The dip of the muzzle is well developed at the moment of passage of the ball from the bore in the off-hand firing.

V. Before discharge, the forces acting on the system are in equilibro —*gravity* and *resistance* thereto; at the moment of discharge a new force is developed, which either destroys the relation of the other forces, thereby producing the *dip* of the muzzle before the ball passes from the bore, or else springs or buckles the barrel.

VI. For a condition of *constraint at its rear end*, the barrel, otherwise unsupported, has no vibration or spring, to the extent of ″.0075, prior to the passage of the ball from the bore.*

---

*NOTE.—May, 1878. W. E. Metford, C. E., in an article on the "Projectory of the Modern Match Rifle," contained in the Spirit of the Times, N. Y., April 13, 1878, gives his views respecting the *cause* of anomaly believed to have been observed for the first time by "The National Guard of the State of New York, a year or so ago."

* * * * * * *

There is a curious anomaly worth mentioning in relation to the zero of rifles.

It is this, that if a thoroughly accurately made pin-hole plug be entered into the breech end of any rifle, the construction of which permits the eye to see through the barrel, and also an aperture plug be entered at muzzle, and if the rifle is then pointed, with its sights set to the zero, ascertained by shooting at the 12 yards, at any object say at 100 yards off, and if then the line of bore be examined, it will be found that there is a very great difference between the two lines; instead of there being only about the inch, the eye line is above the bore line.

It happens in all rifles more or less, and in rifles with the long fore end, such as military rifles; the removing the fore end increases the amount considerably.

A rifle, however, having an *extremely* short barrel does not exhibit this anomaly. This peculiarity will develop vertically if the rifle be shot as usual, but horizontally if the rifle be fired horizontally.

The best way to develop this fact is to shoot at such a distance as not to mix up the gravity pull with it, say at 25 yards, when the fall is half an inch only.

The anomaly is no doubt due to the total mass of the rifle being non-coincident with the axis of the bore, and on the jerk of recoil being given (it is like a sharp blow to the rifle, as it happens in less than a three-hundredth of a second), the rifle, instead of a true recoil, has imparted to it such a motion as eventually causes the muzzle to jerk up, but of which the first result is to set up a distinct bend of the barrel itself, actually forcing the muzzle *down below* its original line.

It happens that at just about this moment the bullet passes the muzzle, and so it strikes *lower* on the target than if there had been no such action. In fact it is similar to the action of a fishing-rod, which, if watched while a "strike" is being made, will exhibit some way three-quarters up a neutral point, above which the rod will actually move the contrary way for a short time, before the rest of the rod drags this upper part back.

It is easy to comprehend this objection, that the barrel, especially of a match rifle, is too stiff to allow of this; but first it is the fact that such a barrel can be easily sprung, even with the two hands, a very eyeable amount out of truth (of course it goes back again), and that the jerk of the kick is in actual fact like the blow of a hammer.

* * * * * * *

From the record of experiments at the National Armory it will be seen that this anomaly was noticed in 1874, and investigated in 1875 and 1876, prior to the National Guard observation. Attention was first drawn to it in the following manner:

Owing to the drop or fall in practice of the carbine cartridge ball at 500 yards, and at greater ranges, as compared with that of the rifle cartridge, you sought to improve the performance of the former by the substitution of a *paper lining* for the *wads* used in order to compensate the space in the shells due to less powder charge (55 instead of 70 grains). At that time, November 7, 1874, a carbine was carefully adjusted with globe and peep-sights and fired by a skillful marksman, in my presence, at a target 300 yards removed. The carbine *service*, carbine experimental, and rifle cartridges were fired in regular sequence, and the point sighted was the same for all the cartridges. The elbow rest was employed for uniformity of aim and a target record of sixty shots made (20 for each kind of ammunition). The *center of impact* for the carbine cartridges having an initial velocity of 1,080 feet was 5″.7 above and ″.9 below the point sighted, and for the rifle cartridge having an initial velocity of 1,210 feet, 2″.45 below the point sighted. This result was so contrary to all reason, and the reverse of all comparative records at 500 yards and greater ranges, that on December 17, 1874, the anomaly (which had accidentally been discovered) was verified by making a target record of 20 shots each, for the rifle and carbine cartridge, and the *center of impact* was determined to be 4″.35 *above* for the carbine cartridge ball and 6″.8 *below* for the rifle cartridge ball, each cartridge being fired *alternately*, with the same aim from the carbine, using the globe and peep-sight, the range being 300 yards. The records, November 7 and December 17, 1874, are exhibited on the diagram sheet of targets, marked A and B. In conducting later experiments, to ascertain initial velocities for various powder charges, it was found that when an elevation was established for a light charge of powder to strike the small velocity target (using globe and peep-sight), that this same elevation would cause the ball fired with a heavy charge to strike much below the point sighted. These are the facts which led to the investigation contained in this report, and which it is deemed proper to present, in view of the fact that at this time the subject has attracted attention.

VII. Invariable results are attained with the "fixed rest" firing, *other things* being equal, and the effects of practical *corrections* made to eliminate errors of elevation for "off-hand firing" appear again as errors when the fixed rest is employed.

VIII. Partially locking the arm in the fixed rest permits of motions *similar* to those noticed in off-hand firing, quite as anomalous, and to be accounted for in the same manner.

CONCLUSIONS.

First. These experiments show that no method is so well calculated to discover or determine the proper angles of elevation for small-arms as practical tests of firing, when the conditions are *no more perfect* than it is possible for the soldier to attain in service.

Second. Interchange (which is contingent) of ammunition for the rifle and carbine will disconcert the marksman in his estimate of elevations—the necessary corrections for short ranges being the exact opposite of what it is reasonable to expect. Facts of this nature show the absolute necessity for invariability of ammunition, if the true value of an arm is to be derived.

Third. The "fixed rest" eliminates errors that develop in the natural order of firing, and for this reason should not be employed to establish the practical angles of elevation on the sight scale.

Fourth. Recoil is generally regarded as the direct action or effect of a single force, but may better be defined to be the resultant of several forces, all more or less dependent upon their points of application, and the relation of these points to the center of inertia of the system. It does not affect accuracy of fire in the sense of increasing the mean deviation from the center of impact (this has time and again been shown at the armory), since flat trajectories and consequent compact clustering of shots result from high velocities and proportionate recoil. It is shown, however, by the record of this trial, to *determine the position* of the center of impact in the vertical field of fire, and within certain range limits produces an effect the reverse of what is anticipated. Under similar conditions of arm and ammunition its effect is *constant*, and being determined by practical observation may be compensated in the regulation and adjustment of the sight scale.* For constant angles of elevation under *variable* conditions of ammunition, or methods of supporting the arm when fired, its effects are manifest at once.

*NOTE.—May, 1878. This is the best practice made at the armory with the Springfield rifle as a military arm without globe and peep-sight or hair-trigger, the errors due to recoil in the vertical field and to drift and wind in the horizontal field being compensated by the adjustable rear sight.

Kind of rifle, Springfield.
Kind of ammunition, service.
Distance, 500 yards.
Size of targets, mode of marking and aiming, same as at Creedmoor.

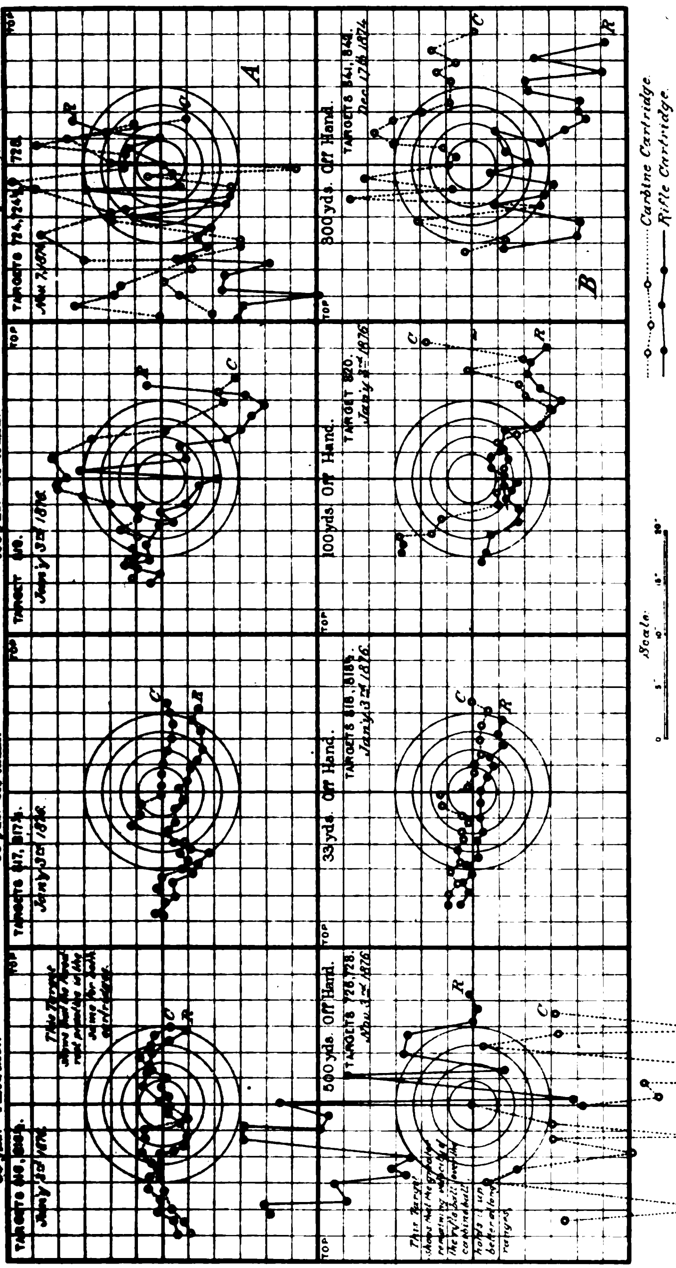
Names.	Number of shots.										Total.	Remarks.
	1	2	3	4	5	6	7	8	9	10		
L. F. Bruce	5	5	5	5	4	4	5	4	3	5	45	Adjustable rear-sight.
M. W. Bull	4	5	5	5	5	5	5	5	4	5	48	
R. T. Hare	5	5	5	5	5	4	5	5	4	4	47	Mean, 46.5 points.
J. F. Cranstor	4	5	5	4	4	5	4	5	5	5	46	Maximum, 50 points.

PLATE I.

TARGET RECORD FOR CARBINE, [GLOBE AND PEEP SIGHT]

ALTERNATELY FIRING CARBINE AND RIFLE CARTRIDGES.

RECORD DEVELOPED HORIZONTALLY FOR PURPOSE OF COMPARISON.



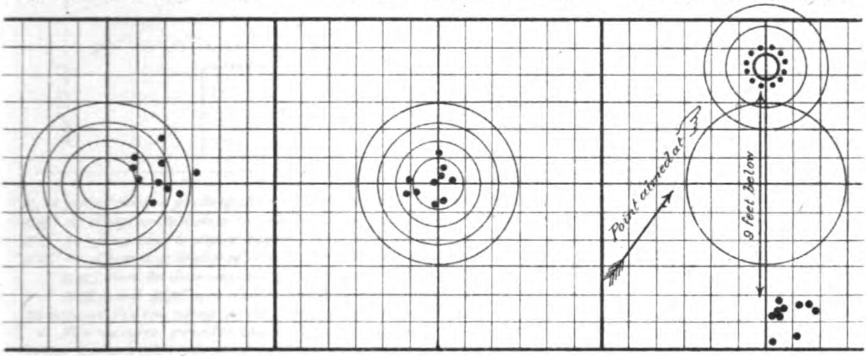
Note —— *The Targets marked 'A' were made with a view of comparing the paper lined Carbine Cartridge, with the wad Carbine Cartridge believing that the former would hold up better than the latter; when to my surprise both cartridges held up above the rifle cartridge.*
The Targets marked 'B' were made to confirm this anomaly. *J. P. F.*

Accompanying Appendix O 1878

No. 1.
513 YARDS
OFF HAND WITH
500 YARD ELEVATION 1° 18′ 3″

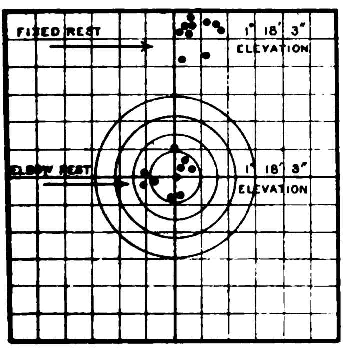
No. 2.
500 YARDS
ELBOW REST WITH
500 YARD ELEVATION 1° 18′ 13″

No. 3.
500 YARDS
FIXED REST WITH
300 YARD ELEVATION 0° 45′ 0″



Light breeze from the left.

No. 4.
THIS TARGET IS MADE
FROM THE RECORD OF No. 3 & No. 2,
CORRECTING FOR ELEVATION.
POINT OF REFERENCE, CENTRE OF TARGET.



No. 5.
THIS TARGET IS MADE
FROM THE RECORD OF No. 3 & No. 2.
POINT OF REFERENCE, CENTRE OF TARGET.

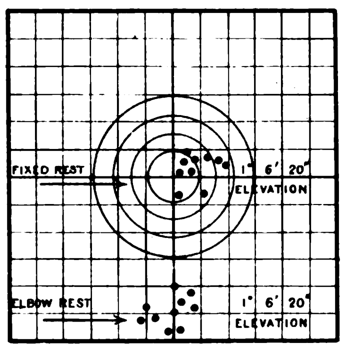
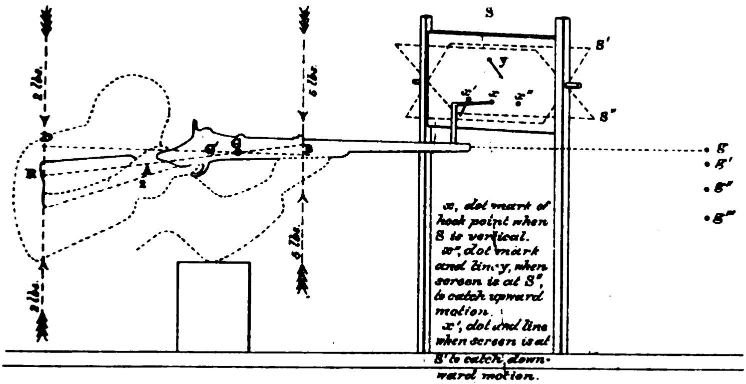


Fig. 1.



g, is point where prolongation of axis of bore pierces plane of target.
gg' is drop or fall due to gravity alone variable for different ranges.
g'g'' is drop due to dip of barrel, for a light charge of powder.
g'g''' is drop due to dip of barrel, for a heavy charge of powder.
gg' can be determined by calculation $h = \frac{1}{2}gt^2$
g'g'' and g'g''' are determined by experiment these values are constant for the same arm, ammunition, and range.
• *For ranges greater than 300 yards g''' will be above g'' the carbine being used with rifle and carbine cartridges.*
For ranges less than 300 yards g''' will be below g''.

Fig. 7.

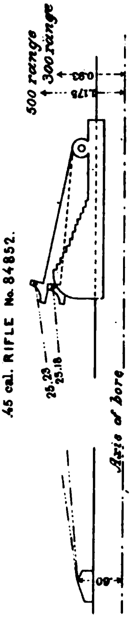


Fig. 2.

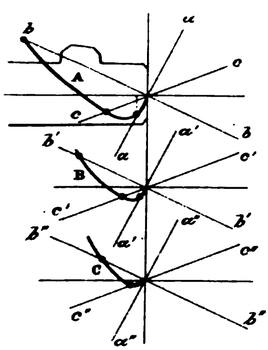


Fig. 3.

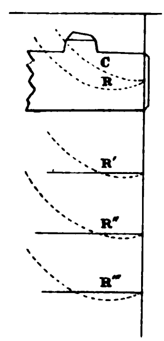


Fig. 6.

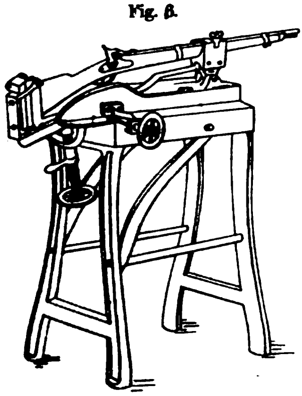


Fig. 4.

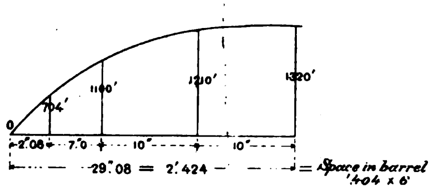
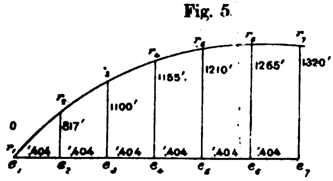


Fig. 5.



APPENDIX P.

REPORT ON LIFE-SAVING APPARATUS, GUNS: PROJECTILES, ETC., BY FIRST LIEUT. D. A. LYLE, ORDNANCE DEPARTMENT U. S. ARMY.

(Fifty-four plates.)

NATIONAL ARMORY, SPRINGFIELD, MASS., *August* 16, 1878.

SIR: I have the honor to submit herewith my report upon life-saving apparatus.

Fifty-four plates accompany the report.

Very respectfully, your most obedient servant,

D. A. LYLE,
First Lieut. Ord. Dept. U. S. Army.

The CHIEF OF ORDNANCE, U. S. A.
(Through the commanding officer, National Armory.)

CONTENTS.

CHAPTER III.

GUN-CARRIAGES.

Section I. *Carriages for 3-inch M. L. rifled mortar.*

Section II. *Carriages for smooth-bore guns.*

CHAPTER IV.

POWDER AND CARTRIDGE BAGS.

Second series of experiments.

CHAPTER V.

SABOTS, FRICTION-PRIMERS, AND IMPLEMENTS.

CHAPTER VI.

SHOT-LINES.

CHAPTER VII.

FAKING-BOXES.

PART III.

CHAPTER I.

FIRING-GROUNDS.

CHAPTER II.

EXPERIMENTS.

Section I. *First series.*

Section II. *Second series.*

CHAPTER III.

VELOCITY AND FORCE OF THE WIND.

PART IV.

CHAPTER I.

HISTORY OF MANBY'S APPARATUS.

CHAPTER II.

CHAPTER III.

THE PARROTT MORTAR.

CHAPTER IV.

HUNT'S PROJECTILE.

CHAPTER V.

CHAPTER VI.

LIFE-SAVING ROCKETS.

APPENDIX.

LIST OF PLATES.

EXPLANATION.

Plate I.

Fig. 1. Horizontal section* through axis of bore of 3″ M. L. rifled mortar. (Converted from an old bronze field-piece.)
Fig. 2. Front elevation.
Fig. 3. Plan and section of copper vent-piece.

Plate II.

Fig. 1. Horizontal section* through the axis of the bore of S. B. bronze-gun A. (Bore 2¼″ in diameter in figure; since bored out to 3″ diameter.)
Fig. 2. Transverse section through axis of trunnions.

Plate III.

Fig. 1. Plan of sinking-head of gun A, showing relative positions of specimens for testing.
Figs. 2 and 3. Elevations of finished specimens before and after cutting screw for holders.
Fig. 4. Plan of sinking-head of bronze gun B, showing relative positions of specimens for testing.
Fig. 5. Plan of sinking-head of bronze gun C, showing relative positions of specimens for testing.
Fig. 6. Sponge and rammer.
Fig. 7. Wiping rod. } Used for extracting cartridges from bore of guns, &c.
Fig. 8. Wiper.

Plate IV.

Fig. 1. Horizontal section* through the axis of the bore of 2″ S. B. bronze gun B.
Fig. 2. Transverse section through the axis of the trunnions.
Fig. 3. Transverse section through the vent.

Plate V.

Fig. 1. Horizontal section* through the axis of the bore of 2¼″ S. B. bronze gun C.
Fig. 2. Front elevation.

Plate VI.

Fig. 1. Side elevation of experimental projectile No. 1 (3″ rifle.)
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section, showing positions of line, cap, washers, &c.
Fig. 4. Transverse section at rear row of studs, showing elevations of latter.
Fig. 5. Plan and elevation of cap.
Fig. 6. Plan and elevation of brass washer.
Fig. 7. Plan and elevation of rubber plug.

Plate VII.

Fig. 1. Side elevation of experimental projectile No. 2 (3″ rifle).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section, showing line, cap, washer, studs, and retaining screw.
Fig. 4. Transverse section through rear row of studs, with elevations of latter.
Fig. 5. Plan and elevation of cap.
Fig. 6. Plan and elevation of brass washer.

* In these sections the axes of the guns are assumed to be horizontal.

Plate VIII.

Fig. 1. Side elevation of experimental projectile No. 3 (3″ S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.

Plate IX.

Fig. 1. Side elevation of experimental projectile No. 4 (3″ S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.

Plate X.

Fig. 1. Side elevation of experimental projectile No. 5 (3″ S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.

Plate XI.

Fig. 1. Side elevation of experimental projectile No. 17 (3″ S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
[This form is recommended for 3″ guns when the bore does not exceed 20 inches in length. Shank would have to increase in length with the bore beyond 20 inches.]

Plate XII.

Fig. 1. Side elevation of experimental projectile No. 6 (2″ S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.

Plate XIII.

Fig. 1. Side elevation of experimental projectile No. 7 (2″ S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.

Plate XIV.

Fig. 1. Side elevation of experimental projectile No. 8 (2″ S. B.)
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section in rear of axial cavity.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.
Fig. 7. Plan and elevation of lead core in axial cavity.
Fig. 8. Plan and elevation of point of projectile.

Plate XV.

Fig. 1. Side elevation of experimental projectile No. 9 (2″ S. B.—Cordes), showing manner of protecting the line from abrasion in passing from the piece.
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section, &c.
Fig. 4. Transverse section.
Fig. 5. Plan and elevation of cap.
Fig. 6. Plan and elevation of brass washer.

Plate XVI.

Fig. 1. Side elevation of experimental projectile No. 13 (2″ S. B).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section; elevation of shank and point.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.

Plate XVII.

Fig. 1. Side elevation of experimental projectile No. 14 (2″ S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank, &c.

Plate XVIII.

Fig. 1. Side elevation of experimental projectile No. 15 (2″ S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.
[This form is recommended for 2″ guns when the length of bore does not exceed 20 or 22 inches.]

Plate XIX.

Fig. 1. Side elevation of experimental projectile No. 10 (2″.5 S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.

Plate XX.

Fig. 1. Side elevation of experimental projectile No. 11 (2″.5 S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.

Plate XXI.

Fig. 1. Side elevation of experimental projectile No. 12 (2″.5 S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.

Plate XXII.

Fig. 1. Side elevation of experimental projectile No. 16 (2''.5 S. B.).
Fig. 2. Rear elevation.
Fig. 3. Longitudinal section.
Fig. 4. Transverse section.
Fig. 5. Transverse section through eye-hole.
Fig. 6. Transverse section of shank.
[This form is recommended for use with 2''.5 guns when the length of bore does not exceed 20 to 21 inches.]

Plate XXIII.

Carriage No. 1 for 3'' M. L. R. mortar.

Fig. 1. Side elevation.
Fig. 2. Plan.
Fig. 3. Rear elevation.
Fig. 4. Side and rear elevations of quoin.

Plate XXIV.

Carriage No. 2 for 3'' M. L. R. mortar.

Fig. 1. Side elevation.
Fig. 2. Plan.
Fig. 3. Rear elevation.
Fig. 4. Side and rear elevations of quoin.

Plate XXV.

Carriage for S. B. bronze gun A.

Fig. 1. Side elevation.
Fig. 2. Plan.
Fig. 3. Front elevation.
Fig. 4. Rear and side elevations of quoin.

Plate XXVI.

Carriage for S. B. bronze gun B.

Fig. 1. Side elevation.
Fig. 2. Plan.
Fig. 3. Front elevation.
Fig. 4. Rear and side elevations of quoin.
N. B.—This carriage is recommended for 2'' S. B. bronze guns.

Plate XXVII.

Carriage for S. B. bronze gun C.

Fig. 1. Side elevation.
Fig. 2. Plan.
Fig. 3. Front elevation.
Fig. 4. Rear and side elevations of quoin.
[N. B.—This carriage is recommended for 2''.5 and 3'' S. B. bronze life-saving guns.]

Plate XXVIII.

Fig. 1. One-half cartridge-bag for 3'' gun.
Fig. 2. One-half cartridge-bag for 2'' and 2''.5 guns.
Fig. 3. Priming wire; one shorter by 2'' recommended.
Fig. 4. "Combination level," showing manner of using, &c.

Plate XXIX.

Fig. 1. Plan of 3″ wooden sabot, ¾″ thick.
Fig. 2. Elevation.
Fig. 3. Plan of 3″ wooden sabot, ¼″ thick.
Fig. 4. Elevation.
Fig. 5. Plan of a Cordes' 3″ sabot.
Fig. 6. Elevation.
Fig. 7. Plan of 2″ wooden sabot.
Fig. 8. Elevation.
Fig. 9. Plan of a Cordes' 2″ sabot.
Fig. 10. Elevation.
Figs. 11, 12. Plan and elevation of 3″ wooden sabot after firing, showing effect of charge, &c.
Fig. 13. Section showing effect of gas entering axial cavity and blowing off cap, &c.
Fig. 14. Fragment of 2″ shot recovered, showing effect of gas penetrating axial cavity.

Plate XXX.

Gunner's haversack.
This will be modified hereafter, except in its general dimensions. (See description.)

Plate XXXI.

Large faking-box, A. (Regulation size.)

Fig. 1. Plan.
Fig. 2. Side, partial section and elevation.
Fig. 3. End, partial section and elevation.
Fig. 4. Side elevation of frame.
Fig. 5. Plan of frame.
Fig. 6. Plan, and partial section and end elevation of "false" bottom.
Fig. 7. Faking-pin.

Plate XXXII.

Small faking-box, B. (Regulation size.)

Fig. 1. Plan.
Fig. 2. Side, partial section and elevation.
Fig. 3. End elevation.
Fig. 4. End elevation of frame and pins.
Fig. 5. Side elevation of frame and pins.
Fig. 6. Plan of frame.
Fig. 7. "False" bottom.
Fig. 8. Faking-pin.

Plate XXXIII.

Experimental faking-box, C. (Large, square.)

Fig. 1. Plan.
Fig. 2. Side, partial section and elevation.
Fig. 3. End, partial section and elevation.
Fig. 4. Elevation of frame and pins.
Fig. 5. Plan of frame.
Fig. 6. "False" bottom.
Fig. 7. Faking-pin.

Plate XXXIV.

Experimental faking-box, D. (Small, square.)

Fig. 1. Plan.
Fig. 2. Side, partial section and elevation.
Fig. 3. End elevation.
Fig. 4. End elevation of frame and pins.
Fig. 5. Side elevation of frame and pins.
Fig. 6. Plan of frame.
Fig. 7. "False" bottom.
Fig. 8. Faking-pin.

Plate XXXV.

Reel and frame.

Fig. 1. Side elevation.
Fig. 2. Plan of frame.
Fig. 3. End elevation, showing crank, &c.

Plate XXXVI.

Carrying braces.

Fig. 1. Waist belt.
Figs. 2, 3. Braces.
Figs. 4, 5. Billets, with snap hooks for frame.
Fig. 6. Perspective view of braces.

Plate XXXVII.

Fig. 1. Firing-ground at Springfield, Mass.
A. Firing-point.
A. B. Ranges.
C. Flag at 300-yard stake from which "drift" of line measured.
D. Anemometer for obtaining surface velocities.
Fig. 2. Gun-platform, &c.
A. Plan.
B. Section.
C. Positions of faking-boxes.
D. Shelter.

Plate XXXVIII.

Manby's shot.

Fig. 1. Elevation showing plaited hide thong.
Fig. 2. Section showing fuses for illuminating.

Plate XXXIX.

Manby's apparatus.

The figures explain themselves.

Plate XL.

Boxer's apparatus.

Fig. 1. Method of stowing line in faking-box, first tier.
Fig. 2. Method of stowing line in faking-box, second tier.
Fig. 3. Side elevation of rocket-frame.
Fig. 4. Front elevation of rocket-frame.
Fig. 5. Plan of box and partial section.
Fig. 6. Side of box, partial section and elevation.
Fig. 7. End elevation.

Plate XLI.

Boxer's rocket, &c.

Figures explained in plate.

Plate XLII.

Colt's armory testing-machine.

Fig. 1. Rear elevation.
Fig. 2. End elevation.

Plate XLIII.

Colt's armory testing-machine.

Fig. 3. Front elevation of weigh-beam apparatus.
Fig. 4. Elevation, partly in section, of certain parts of the strain-indicating apparatus.

Plate XLIV.

Fixtures for testing-machine.

Fig. 5. Plan of one clasp for holding specimen, open.
Fig. 6. Elevation of same, open.
Fig. 7. Plan of clasp, closed.
Fig. 8. Elevation of clasp, closed.
Fig. 9. Scale for measuring elongations after elastic limit is passed.
Fig. 10. Holder.
Figs. 11, 12. Scale used to measure extensions within elastic limit.
Fig. 13. Specimen of bronze.

Plate XLV.

Curves showing extensions of bronze specimens.

Fig. 14. Curve for gun A.
Fig. 15. Curve for gun B.
Fig. 16. Curve for gun C.

Plate XLVI.

Fig. 17. Illustration of original form of specimen, and showing appearance after testing.

Plate XLVII.

Fig. 1. Section of chill and plan.
Fig. 2. Section of furnace and plan.
Fig. 3. Crucible.
Fig. 4. Pouring-ladle.
Fig. 5. Shot with loop and raw-hide strap.
Fig. 6. Barbed shot.
Fig. 7. Mortar.

Plate XLVIII.

Fig. 1. Method of laying the rope (French faking).
Fig. 2. Whale lair.
Fig. 3. Chain-faking.
Fig. 4. Rope ready in basket.
Fig. 5. Paper tube for priming.
Fig. 6. Ball with lid for fuse.
Fig. 7. Stand.
Fig. 8. Cast-iron anchor.
Fig. 9. Rope with stiff loops.

Plate XLIX.

Fig. 1. Mode of faking the rope.
Fig. 2. Whale-faking.
Fig. 3. Chain-faking.

Plate L.

Parrott's projectile.

Plate LI.

Hunt's line-throwing apparatus.

Plate LII.

Chandler anchor-shot.
1. Before firing.
2. After firing.

Plate LIII.

Boxer rocket.
Light for illuminating wrecks.

Plate LIV.

Method of using the life-saving apparatus.

NOTE.—The greater part of these drawings were made by Mr. Emery, National Armory.

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D. A. LYLE,
Lieutenant of Ordnance.

NATIONAL ARMORY, *August* 15, 1878.

INTRODUCTION.

In the early part of the year 1875 the honorable Secretary of the Treasury applied to the Secretary of War for assistance in the prosecution of experiments for the purpose of improving the life-saving apparatus used by the Treasury Department, which, at that time, were under the special charge of Capt. J. H. Merryman, United States Revenue Marine, and requested that an officer or officers of the Ordnance Department be designated to assist Captain Merryman "in these important matters."

On the recommendation of the Chief of Ordnance, the Secretary of War directed that the "Board on Experimental Guns" convened by Special Order No. 221, Adjutant-General's Office, October 10, 1874, of which Major Crispin, Ordnance Department, was president, be charged with the prosecution of these experiments, in connection with Capt. J. H. Merryman, United States Revenue Marine. This action was taken April 12–16, 1875, and Sandy Hook, N. J., was selected as the most favorable locality for these experiments.

The important and multifarious duties with which the Ordnance Board—formerly "Board of Experimental Guns"—was specially charged were so great as not to admit of any one of its members devoting the time necessary for a thorough investigation and discussion of the subject. In view of this fact Captain Merryman recommended, on May 21, 1877, "that an application be made to the Chief of Ordnance for the detail of an officer for this special service." Colonel Crispin, president of the "Ordnance Board," concurred in this recommendation in his indorsement of June 1, 1877, upon Captain Merryman's letter, and further recommended that said officer should place himself in communication with Captain Merryman and the Ordnance Board, "for such suggestions and instructions as may be deemed proper to give him." These recommendations were approved by the Chief of Ordnance June 6, 1877, and Lieut. D. A. Lyle, Ordnance Department, was "specially assigned to this duty, in addition to his regular duties" at the National Armory, Springfield, Mass. This officer entered upon the duty at once, and the results of his labors are embodied in this report.

No claims of great originality are made, as this apparatus, like the Parrott patent, is a direct evolution from the system of Captain Manby, which dates back to the beginning of the present century. The advances which have been made during the past year are the result of careful study and conscientious experiment. The data recorded are of value for future reference. The writer appreciates the fact that many improvements are yet to be made in life-saving apparatus and entertains the hope that his humble efforts may serve as a basis upon which to found future experiments.

PART I.

REPORT.

CHAPTER I.

I. RIFLE PROJECTILES.

The first experiments were made with rifle projectiles fired from a 3-inch muzzle-loading rifled mortar. This method did not prove satisfactory for the following reasons:

I. On account of the lack of simplicity in loading. The detailed operations of loading are given below.

1. Inserting cartridge and ramming home.
2. Inserting junk-wad or sabot.
3. Unscrewing cap on front end of projectile.
4. Removing cap.
5. Inserting line in axial cavity and drawing it through shot.
6. Putting on rubber washer or washers.
7. Putting on metal washer.
8. Tying knot in end of line.
9. Inserting washers and knot in the cavity in the front end of shot and drawing the line taut.
10. Returning the cap to its position.
11. Putting in the retaining screw to hold the cap.
12. Adjusting line in radial slot in base and in longitudinal groove.
13. Twisting the fine wire which passes around the head of the cap about the line to hold it in the prolongation of the axis of the bore and prevent its being cut off by abrasion in passing out of the piece.
14. Inserting projectile in the bore and ramming it home.

II. The liability of the heated gas from the charge to enter the axial cavity and either burn off the line or blow off the cap. The loss of the cap permits the knot and washers to escape, and when the strain comes upon the line it is very likely to be cut by the edges of the axial cavity in front, as is exemplified in Fig. 13, Plate XXIX.

III. The failure of wire ropes (either copper or iron) to sustain the shock of discharge. These ropes or cords were interposed between the shot and line for the purpose of avoiding the action of the flame upon the line. These rigid materials generally broke before the line.

IV. The necessity for the employment of wads and sabots.

V. The diminution of range due to resistance of the air to the passage of the line. This increased resistance of the air was developed by the spiro-conical form assumed by the line in the trajectory, due to the rotation of the rifle projectile.

VI. The twisting of the line due to the rotation of the projectile.

It was judged, from the indications left upon the wooden sabots which were recovered (see Figs. 11, 12, Plate XXIX) after firing, that if a soft-metal sabot had been used the force of discharge would have wedged it in the radial slot of the base and have caused it to cut the line as it was suddenly swung to the rear by the strain, unless a very thick sabot were used. Paper wads were found to be better than wooden sabots.

VII. The greater expense and difficulty attending the manufacture of both guns and projectiles.

After losing the caps belonging to the rifled projectiles, they were fired a few times by inserting them point first into the rifled mortar. The shot reversed after leaving the gun, and retained their axial rotation, though their flight was unsteady.

Solid, smooth-bore projectiles were next tried in the rifled mortar and gave better results. The escape of gas through the grooves was very great, in some instances burning off the line. One shank was broken off in firing, which was due, not to the form of the shank, but to the material, it having been made of high steel instead of wrought iron. No particular difficulty seemed to be experienced in firing smooth-bore projectiles from rifled guns, provided the shanks were long enough to protect the line from the gases which escape through the grooves.

Enough was learned from these experiments to warrant the conclusion that smooth-bore guns and projectiles were better adapted for this purpose than the rifled ones as here applied; and that spiral springs, wire cords, and rubber washers were either useless or annoying, and always more or less impracticable.

II. SMOOTH-BORE GUNS AND PROJECTILES.

After the difficulties first experienced it was determined to cut loose from rifled mortars, rifle projectiles, wire ropes, spiral springs, rubber straps, rubber washers and plugs, brass washers, caps and retaining screws, and seek for a solution of the problem in some system which would combine great simplicity with efficiency, and which would lessen the cost of manufacture and furnish a method whose details would not be so complicated as to be beyond the comprehension of those required to put it in practice.

1. SMOOTH-BORE GUNS.

The second attempt was made with smooth-bore guns. Bronze was selected as the material from which to make the experimental guns, for the following reasons: On account of its great ultimate tenacity, its ductility, its combination of great strength with light weight, its freedom from destructive corrosion when exposed to the moisture of sea-coast stations, its non-liability to sudden rupture, its availability for recasting, and its value as old bronze after condemnation. Guns made from this material are easily kept in order, as the bores do not rust, a fact of considerable importance with small calibers, on account of the difficulty of cleaning the bore. They are not liable to burst explosively, by reason of their ductility, and when worn out they may be sold for a fair price as old bronze. The only external injury to which they are liable is the bending of the trunnions.

The internal injuries resulting from the powder, such as enlargement at the seat of the charge, and cavities produced by the melting away of the metal by the heat developed by the explosion of the charge, are not serious. The erosive action of the gases is not great, because of the almost entire absence of windage. The wear of the vent is obviated by the use of copper vent pieces. Lodgments and enlargements are not produced in these guns, since projectiles nearly the length of the bore are used and therefore there is no balloting. The bore may be scratched by projectiles and sand, but that is not a serious injury. The softness of the metal, and its proneness to deterioration under rapid firing which

causes heating, though grave objections to the use of bronze for field-pieces, do not affect its use for this service, where rapid firing is never resorted to, consequently there is little danger of heating or of melting the metal of the bore. Small charges of powder are generally used, therefore little is to be apprehended from excessive erosion.

2. PROJECTILES.

Full descriptions of these are given in a subsequent part of this report. These projectiles are modifications of Captain Manby's shot. The caliber and weight have been reduced. The lengthening of the bore, the suppression of a greater part of the windage, and the employment of improved lines, have increased the *effective* force of the powder, diminished the resistance which the projectile and line experience from the air, and have extended the range. It will be seen that the weights were increased as the experiments proceeded; this resulted in decreasing the initial velocity and the consequent violence of the vibrations of the line when the charge of powder remained constant. These projectiles are carefully turned and finished to fit the bore of the gun accurately. The careful method of finishing renders them more expensive, but even then they are cheap. Few of them are required, and the resulting efficiency counterbalances the extra cost. As in the Parrott gun, the bore of the gun must be kept clean and the projectiles free from rust.

The gun being of bronze, no difficulty is encountered in keeping the bore clean. The few projectiles at each station are easily kept free from rust by the men. Experimental projectiles Nos. 15, 16, and 17 are the ones recommended for use with 2″, 2″.5, and 3″ guns respectively. The 2″ projectile will be the most expensive, as it has to be bored out and filled with lead to increase its weight. But even its cost is trifling as compared with rockets and some patented projectiles. Lead projectiles similar to experimental projectile No. 13 are found to upset more or less, to lead the bore, and to strain the gun greatly. Wrought-iron projectiles scratch the surface of the bore badly.

3. SHANKS.

These were found to be of great importance. By prolonging them near to or beyond the muzzle of the gun when it is loaded, they keep the line from being cut off by the passage of the projectile, and do away with the necessity for a line-supporter. Several kinds of shanks were used. It was found that with very short shanks, the line would be burned off where tied in the eye. It was suspected that this arose partly from the shortness of the shank and partly from the shape of the base. The gases which pass over and around the shot at the first instant of expansion would follow the incline of the frustum and converge at and near the apex of the cone produced. The apex was near the eye-hole of the short shanks. Then a longer shank was tried, and that portion of its length between the base of the shot and eye-hole polished brightly, in order to ascertain, if possible, whether the gas converged at any point upon the shank; and, if so, where. The result confirmed the hypothesis, and a very dark stain showed the maximum convergence of the gas to be about the apex of the cone, whose frustum formed the base, or, perhaps, a little in front of it. Long shanks were afterwards used, and with great success. The earlier shanks were made of whatever scrap could be obtained for the sake of economy. At first the thread ex-

tended an inch and a half into the shot, but the junction of the thread and body was found to be a point of weakness, which should have been anticipated, especially as it came directly at the base of the shot, where the greatest strain was thrown on the shank when the projectile reversed. They were found to bend and crack at this point. The next step was to shorten the length of the screw-thread and let the body of the shank extend a short distance into the shot. This was an improvement, but continued practice upon hard earth showed that the shank could be bent and was still weak. A shank forged from wrought iron, with the dimensions increased, was then made and adopted. It may be seen in experimental projectiles Nos. 15, 16, and 17. A few very long shanks were tried and behaved very well. The shanks should always be of the best wrought iron, and should be carefully forged and finished. A steel shank, that was made by mistake, broke off in firing, showing that material to be too brittle for this purpose.

III. GUN-CARRIAGES.

The gun-carriages are made with wooden cheeks, bound with iron. They combine elasticity with strength, and act well upon sandy beaches. The wrought-iron handles increase the ease with which they may be carried. If necessary the gun may be dismounted, and carried by one man upon his shoulder, while another takes the carriage. Two projectiles may be placed upon the rear transom and the whole carried easily by four men. The small gun and carriage are intended to be carried by two men; here, as before, the projectiles may be placed upon the rear transom. The load may be balanced by sliding the hands along the handles. The addition of iron cheek-straps increases greatly the durability of the carriage. The carriages for guns C and B are the ones recommended for adoption. The vent pieces of the guns project high enough to avoid difficulty in the use of friction primers at ordinary angles of elevation. Gun B and carriage are too light to be used with ordinary friction primers without some danger of disturbing the pointing of the piece, as the primers pull off too hard.

IV. SPONGE AND RAMMER.

A single staff, with a rammer head on one end and a sponge on the other, constitutes this implement.

V. WIPING-RODS.

These were made from old condemned musket ramrods of obsolete pattern. One end is curved to form an eye, and a corkscrew wiper is screwed on the other end. This is useful for withdrawing cartridges when necessary, and, with flannel or cotton waste wrapped around the wiper, is valuable for cleaning the bore of the gun. It also may be used as a rammer for pressing home the cartridge, by reversing it and inserting the eye end in the bore.

VI. PRIMING-WIRES.

Two of these are issued with each gun, as one may be lost. They are made of steel or brass wire, preferably of the former.

VII. GUNNER'S HAVERSACK.

One of these should be issued with each piece, to be carried by the keeper of the station. The cartridges, friction primers, priming-wires, lanyard, combination level, and a piece of flannel for use with the wiper are carried in this pouch.

VIII. POWDER.

No particular kind of powder has ever been adopted for use at the life-saving stations. "Pebble" powder was deemed too large grained, and "rifle" powder too fine grained for this service. Four different specimens of powder were procured from the Hazard Powder Company.

The tests for initial velocity, which will be given upon subsequent pages, show that Navy cannon powder gives a good initial velocity for a not excessive strain or pressure. That test, however, was not a fair one for this powder, which, on account of its large grain, was more or less broken and compressed in loading the metallic shells. It is probable that both the velocity and pressure are too great as given. The uniform action of this powder during the experiments was such as to commend it to very favorable notice. Musket, rifle, and duck-shooting powders are all more or less quick and violent in their action. The musket (Hazard) is very uniform, but quite too rapid in its inflammation. A direct comparison of these powders was made, with the results given below.

Comparisons of different kinds of powder.

[Maker: Hazard Powder Company. Gun: 2".5 bronze gun C. Charge of powder: 3 ounces in every case; carefully weighed. Projectile: Experimental No. 16, marked "L. 12." Weight of projectile: 12.75 pounds. Shot-line: Linen No. 7 (Silver Lake); same line as used in first series of experiments. Faking box: Box A. Place: Sandy Hook, N. J. Date: May 6, 7, and 8, 1878. The same projectile, line, and faking-box were used throughout the comparison.]

No. of round.		Kinds of powder.			
		Navy cannon.	Mortar.	United States musket.	Sea-shooting duck.
		Yards.	*Yards.*	*Yards.*	*Yards.*
1	Ranges in yards	281⅔	284	292½	308⅓
2	......do	280	267⅔	284	293⅓
3	......do	266⅔	263⅓	289	300
4	......do	281⅔	269	280½	272
5	......do	280⅔	261	263	286⅓
	Total	1,390⅔	1,345	1,409	1,460
	Arithmetical mean	278.13	269	281.8	292
	Greatest variation from mean	11.47	15	18.8	20
	Least variation from mean	1.87	....	1.47	1.33
	Mean variation	4.58	6	8.1	10.2

From the above table it will be seen that the Navy cannon-powder acted very uniformly, four of the five shots being almost identical. The "sea-shooting duck" is represented as giving the best mean range; this is explained by the difference in the velocities of the wind. The wind was light when the "duck" powder was used.

The Navy cannon is much coarser grained than the musket or rifle powder, but is not so coarse but that most, if not all, of it is consumed before the projectile leaves the piece. Army cannon is too coarse

grained; a portion of the charge is lost by being blown from the gun before completely consumed. Selecting from the samples tested, the preference should be given to the Hazard Navy cannon. The effect of a powder depends more upon the manner of loading than has been supposed by those who are not accustomed to dealing with it. A charge of Navy cannon can, by two or three forcible jams of the projectile when inserted in the bore, be so compressed and the grains so broken as to exhibit all the violence of a fine-grained powder. Powder stored along the coast is exposed more or less to the moisture of the sea-air and deteriorates very rapidly. Since only small quantities are kept at the life-saving stations, the powder should be renewed annually and the stock on hand used for drilling and exercising with the apparatus.

IX. SHOT-LINES.

On a comparison of the tables of the breaking weights of the different shot-lines it will be seen that, in every instance except two, the linen lines are stronger than the hemp. It will also be noted that the linen lines have more stretch per linear foot than the hemp lines. The tables, &c., may be found upon subsequent pages. The braided linen lines have proved superior in usefulness to the hemp. The preference should be given to unbleached linen thread for the manufacture of shot-lines. Great care should be taken that none but the best thread be put in such lines, and that in braiding a continuous line, when the spools are changed, they should not all be changed at the same moment, else a weak spot is the result. Bleaching of any kind is harmful. Hemp is too brittle and becomes very harsh after a few shots. The waterproof lines pass through the air with less friction than those having the ordinary finish, and generally attain a better range. The vibrations of the line due to faking is the greatest danger to which it is subjected. These vibrations reach their maximum amplitude in the first part of the trajectory, when the velocity of the shot is greatest. A place varying from 20 to 40 yards from the shot seems to be the critical point. In that vicinity the line generally breaks. It is a case quite similar to that of snapping a whip and breaking off the farther portion of the lash. There is little doubt but that long storage of lines will destroy their good qualities. Lines after being stored for a year or two should be used for practice drills. New lines when first received are stiff and refractory; this makes them difficult to fake. They should be wound from the original coil upon a reel, to avoid twisting, and should be fired once or twice with light charges of three or four ounces of powder. This usage will make them a little more flexible, so that they can be faked with less trouble. New lines if possible should be used when firing over wrecks. There should always be more than one good line at the station, for a line once wet becomes difficult to handle. New lines have not had the stretch taken out of them by firing, and consequently are not apt to be broken should it be necessary to fire with heavy charges.

X. FAKING-BOXES.

These are boxes, peculiarly constructed, to contain the shot-lines and preserve them in readiness for firing at a moment's notice. Their size varies with the diameter and length of line to be stored for service. It has been found that the less the boxes in length and width, the better they were adapted to prevent the rupture of the shot-line, in consequence

of the necessary shortening of the fakes in the line. Experiment showed that short fakes or loops of line diminished very markedly the length or amplitude of the vibrations in the line when running out of the box. In the case of long fakes, the line would break at the bend, or change of direction of the line, before its inertia was overcome. The effect was the same as if the line had been nailed fast at the ends of the fakes. This was especially noticeable in the case of hemp lines, whose fibers are very brittle though very strong. In the effort to diminish the lengths of the fakes, experiments were made with boxes of lesser length and width than those used in service at present. This required the faking-pins to be longer. This alteration demanded a much deeper faking-box and one that had to have some method devised to hold it at the proper inclination when about to fire. This form of box failed for the following reasons, namely: the faking-pins were so long that they bent toward each other unduly in the process of faking, rendering it somewhat difficult to disengage the line from them at the critical moment, and bringing such a strain upon the frame that it was liable to split. To remedy these defects the frames and faking-pins would have to be made heavier and longer, which would add to the weight of the box; a result not desired. Increasing the depth of the box weakened it and made it more liable to be broken by the successive impacts of the vibrating fakes, which are always severe. It was found advisable to keep the height of the pins the same as at present and to make the boxes of a size just capable of holding the shot-lines, provided that in no instance should the boxes be longer than three feet. Four sizes of boxes were used, marked, respectively, A, B, C, and D. Boxes A and B are the sizes now used in the service; C and D were designed and used with lines No. 5 and No. 3½, respectively. It was found that the life of a wooden faking-box, when heavy charges of powder are used, is short. The vibrations of the line, especially the lateral ones, which originate in the change of the line from tier to tier of fakes, are powerful enough to split the ends of the box and to start the dovetailing after a few shots. In fact, the ends of the box are sometimes split at the first fire. The split usually occurs about four inches from top of the box. The natural vibrations of the line, due to its position in the tiers of fakes, would be in diagonal planes nearly at right angles to each other; this gives rise to a resultant vibration, whose plane is variable, depending on several changing circumstances. When this resultant plane happens to assume a position perpendicular to the bottom and longer axis of the faking-box, either the bottom or the uppermost side of the box, and sometimes both, are liable to be split. The plane of resultant vibration is so unstable in position that this does not often occur; the ends are much more apt to be split. It was found that the interior edges of the box acted as knife edges, cutting the rapidly paying-out lines, and this, too, when the boxes are made of soft pine and the edges are angles of 90°. The velocity of the passage of the line, together with the striking due to the vibrations, compensated for the unfavorable nature and material of the knife edge. The edges were rounded and no further difficulty was experienced from that cause. Sometimes the entire line was carried out, the end being taken in some instances more than 100 feet in front of the box. Should this occur in service, the shore end might be carried out into the water and be beyond the reach of the surfmen, though perfectly successful in all other particulars. To prevent this, a small notch, about the size of the diameter of the shot-line, is cut in the side of the box, and all its edges and corners carefully rounded and smoothed. Similar notches (which need not be rounded) are cut in each side of the "false" bottom. Then, after faking the line,

the operator leads the end in his hand down one side of the tiers of fakes to either of the notches in the "false" bottom, and the assistant puts the faking-box over the rope and pins, with the notch in the box on the side where the line is led out; this allows the box and frame to be fastened together without trouble, and leaves the shore end of the line hanging from the box. In firing, the *notched* side of the faking-box is placed *uppermost* and the protruding end made fast to another line on shore, to obviate the danger of its loss by being hauled out to sea. In the service boxes, the frames and boxes are held together by two staples and a hook. The latter was always coming out, exposing the frame and line to the chances of falling and becoming entangled in transportation. Hasps and turn-buttons were tried on the experimental boxes; these, though safe, sometimes gave trouble in getting ready for firing when in great haste, and, the button being on the box, it was thought to give an opportunity for the line, when vibrating or whipping, to catch and be cut off. Hasps, staples, and lever snap-hooks are now recommended for trial. The boxes now made have the corners strengthened for about five inches with yellow metal (an alloy of tin and copper,) angle pieces at each corner near the bottom—*top* when in position for firing.

XI. EXTENT OF RANGE OF SHOT-LINE.

In most all of the accounts of trials and experiments with line-carrying apparatus, the subject of *range* seems to be the only one considered.

If the attention of inventors is called to the fact that *accuracy* also is in some degree required, they immediately wander from the point, and bring up the fact of the slight deviation of their projectiles from the plane of fire as conclusive evidence that their method is perfect.

The minimum lateral deviation or *accuracy* with which a line can be extended a given distance is a matter of vastly more importance than apparently has ever been accorded by experimenters. The deviation of the projectile is seldom excessive, while the bowing or *drift* of the line may be out of all proportion.

What advantage accrues if a range of a mile be obtained when at every shot the line falls clear of the vessel by perhaps many yards, due to the lateral drift of the line from the effect of the wind? The *drift* or lateral deviation of the shot-line from the plane of fire increases with the lightness of the line, the increase in the angle of elevation of the gun, and the diminution of axial tension upon the line; and, lastly, it depends greatly upon the horitzontal angle that the directions of transverse winds make with the plane of fire. The effect of the wind is greatest when this angle is 90° or blowing directly across the plane of fire. With light lines, longer ranges but less accuracy are obtained. The greatest range on record for a mortar and line-carrying projectile was obtained with gun A and a Silver Lake braided linen line No. 3½. This range was 694⅔ yards, measured distance.

The greatest range heretofore obtained with a mortar was 631 yards, reported by Captain Ottinger. How accurately this range was measured, or whether the distance was only estimated, or what size of line was used is unknown to the writer; but that the mortar was very much heavier than the one used in the case above cited is beyond doubt.

A range of 400 yards is understood to be about the maximum range necessary for the requirements of the service along our coasts, and it is not probable that a hawser and life-car can be used with success over even so great a distance.

XII. VELOCITY OF THE WIND.

The velocity of the wind given in the tables of fire is not the actual velocity at the instant of firing. The results are the mean velocities of the wind during the intervals between the shots. This interval varies generally from 10 minutes to 40 minutes. The method of obtaining the velocities is as follows: A reading of the anemometer was taken a few minutes before the first shot upon any given day, together with the time of observation; the second reading was taken directly after the first shot; the third reading was taken directly after the second shot, and similarly for the subsequent shots. From these times and readings the mean velocity of the wind during the intervals was computed.

It was found by observation that the velocity of the wind was constantly changing and came in variable puffs; that it would freshen up for a moment or two and then die away more or less. The intervals between the observations would often comprise several of these alternate maximum and minimum periods. In order that the mean velocity (the one recorded) should always fall *below* the *actual* velocity at the instant of firing, the piece was not fired until the wind freshened and was blowing with its greatest force.

The surface velocity of the wind appeared generally to be less than that above the ground at the summit of the trajectory. This was seen in the effect upon the line, especially when the wind was blowing directly across the plane of fire. The anemometer for surface velocities was always placed opposite the 200-yard stake, except during the last few days of the experiments, when it was situated 50 yards in front and to the right of the firing-point. It would have been placed near the 300-yard stake, but for the fact that the labor, already great, of walking down and back after every shot would have been increased. The writer took all readings himself, and either loaded the piece or was present every time it was loaded and fired during the experiments. This necessitated a great deal of toil through the sand.

During many gales and storms for the past year observations were made as to the frequency in duration of the temporary lulls of the wind.

These were found in the generality of cases to occur often and to last for a varying interval of time, ranging from 7 to 20 seconds. Now, experiments show that line-carrying projectiles rarely occupy more than 8½ seconds in their flight, and that it takes from 5 to 15 seconds more for the line to settle to the ground, depending upon the angle of elevation at which the gun is fired and the weight of the line. Here, then, for extreme cases it may be seen that an interval of about 25 seconds, and in ordinary cases about half that period, is required to fire the piece and to allow the shot to describe its trajectory and the line to settle upon the ground or water. Therefore the piece, in case of wreck, should be prepared for firing, and, with lanyard taut, the gunner should await the favorable lull or moment of least violence in the gale, and then fire the piece without loss of time.

CHAPTER II.

LIFE-SAVING APPARATUS.

RECOMMENDATIONS.

The following guns and projectiles are recommended for the Life-Saving Service:

The caliber of the gun will depend upon the size of line used and the range required.

For ranges of 300 yards and less, with heavy lines (larger than No. 7), a 3-inch gun should be used.

For ranges of 400 yards and less, with service braided lines between Nos. 4 and 7, a 2.5-inch bronze gun should be used.

For ranges of 250 yards and less, with service lines between Nos. 4 and 7, a 2-inch bronze gun will be sufficient.

It will be seen by comparing the above recommendations with the records of firing that the writer has allowed a wide margin or factor of safety, as far as range is concerned, for even the 2-inch bronze gun (B) has no recorded range of less than 278 yards, and that too with a heavy No. 7 line.

I. BRONZE LIFE-SAVING GUNS.

These guns are intended to be used in connection with projectiles having lines attached to them for the purpose of effecting communication between the shore and stranded vessels; or, under favorable circumstances, they may be used on shipboard for throwing lines to the shore. These guns are chill-cast, having smooth bores of 2″, 2″.5, and 3″ in diameter, respectively.

1. 2.5-INCH LIFE-SAVING GUN.

[Model: Bronze gun C. Caliber: 2.5 inches=6.35 centimeters.]

(Plate V.)

The exterior of this gun is divided into four principal parts, viz, the *breech*, the *first reinforce*, the *second reinforce*, and the *chase*.

The breech is a hemisphere whose radius is equal to the semi-diameter of the first reinforce.

The first reinforce is cylindrical, and extends from the base of the breech to a point in front of the axis of the trunnions.

The second reinforce is a short frustum of a cone, joining the first reinforce to the chase. The latter is cylindrical, and is of a lesser diameter than the first reinforce.

The chase is terminated in front by the *face* of the piece without any swell of the muzzle or muzzle-band. The cascabel and trunnions are short cylinders.

The rimbases unite with the exterior surface of the gun by tangent-curved surfaces.

The vent piece is of copper. The vent is perpendicular to the axis of the bore, and is 1.25 inches (=3.175 centimeters) from the bottom of the bore.

The bore is cylindrical, and is terminated at its lower extremity by a hemispherical chamber, by which term it is proposed to designate the bottom of the bore.

Nomenclature.

A—Breech.
B—First reinforce.
C—Second reinforce.
D—Chase.
E—Chamber.
F—Bore.
G—Trunnions.
H—Rimbases.
I—Cascabel.
V—Vent.

Dimensions, &c.

	Inches.		Centim'rs.
Diameter of first reinforce	5.5	=	13.97
Diameter of chase	4.5	=	11.43
Diameter of bore	2.5	=	6.35
Diameter of trunnions	2.0	=	5.08
Diameter of rimbases	2.8	=	7.112
Diameter of cascabel	1.5	=	3.81
Diameter of vent	.2	=	.508
Radius of breech	2.75	=	6.985
Radius of chamber	1.25	=	3.175
Radius of chase	2.25	=	5.715
Length of first reinforce	8.50	=	21.59
Length of second reinforce	2.00	=	5.08
Length of chase	9.5	=	24.13
Length of bore, exclusive of chamber	18.75	=	47.624
Total length of bore	20.00	=	50.799
Length of trunnions	2.0	=	5.08
Length of rimbases	.1	=	.254
Length of cascabel	1.5	=	3.81
Distance of vent from bottom of bore	1.25	=	3.175
Distance between the rim bases	5.7	=	14.478
Total length of piece	24.25	=	61.594

Weights.

	Lbs.		Kilos.
Weight of piece	108.25	=	49.096+
Preponderance	1.5	=	0.680+

2. 2-INCH LIFE-SAVING GUN.

[Model: Bronze gun B. Caliber: 2 inches = 5.08 centimeters.]

(Plate IV.)

This gun is of the same general form as gun "C" (2″.5), but is much smaller and lighter.

Nomenclature.

A—Breech.
B—First reinforce.
C—Second reinforce.
D—Chase.
E—Chamber.
F—Bore.
G—Trunnions.
H—Cascabel.
V—Vent.

Dimensions, &c.

	Inches.		Centim'rs.
Diameter of first reinforce	4.0	=	10.16
Diameter of chase	3.5	=	8.89
Diameter of bore	2.0	=	5.08
Diameter of trunnions	1.75	=	4.445
Diameter of cascabel	1.5	=	3.81
Diameter of vent	.2	=	.508
Radius of breech	2.0	=	5.08
Radius of chamber	1.0	=	2.54
Radius of chase	1.75	=	4.445
Length of first reinforce	8.0	=	20.32
Length of second reinforce	1.0	=	2.54
Length of chase	9.0	=	22.86

Length of bore, exclusive of chamber	17.0	=	43.179
Total length of bore	18.0	=	45.719
Length of trunnions	1.5	=	3.81
Length of cascabel	1.5	=	3.81
Distance of vent from bottom of bore	1.25	=	3.175
Distance between the rimbases	4.0	=	10.16
Total length of gun	21.5	=	54.609

Weights.

	Lbs.		Kilos.
Weight of piece	54.25	=	24.607+
Preponderance	1.0	=	.453+

[NOTE.—A 3-inch (= 7.62 centimeters) gun may be made differing but slightly in weight and dimensions from the 2½-inch above given. The model is essentially the same in both.]

II. PROJECTILES.

1. 2.5-INCH PROJECTILE.

Diameter, 2.5 inches=6.35 centimeters.

(Plate XXII.)

This is a solid cast-iron shot. The form is cylindro-ogival. A frustum of a cone forms the base.

The radius of the ogival head is equal to one diameter of the shot. A wrought-iron shank is screwed into the base, having an eye at its posterior extremity for attaching the shot-line.

Dimensions.

	Inches.		Centm'rs.
Total length	15.7	=	39.877
Length of ogival head	2.17	=	5.5118
Radius of head	2.5	=	6.350
Length of cylindrical part	12.43	=	31.5712
Diameter of cylindrical part	2.5	=	6.350
Length of frustum	1.1	=	2.794
Diameter of smaller base of frustum	1.35	=	3.429
Shank—Total length	6.5	=	16.510
Length of screw	1.5	=	3.810
Diameter of screw	1.0	=	2.540
Length from plane of base	5.0	=	12.700
Distance from base to center of eye-hole	4.5	=	11.430
Diameter of eye-hole	.4	=	1.016
Width at eye	1.0	=	2.540
Thickness at eye	.4	=	1.016
Diameter of neck	.625	=	1.5875
Distance of center of gravity from plane of base	7.45	=	18.923

Weight.

	Lbs.		Kilos.
Weight, about	19	=	8.61+

2. 2-INCH PROJECTILE.

Diameter, 2 inches=5.08 centimeters.

(Plate XVIII.)

This projectile is similar to the larger calibers, being cylindro-ogival in form, with a conical frustum for its base. The radius of the ogival head is equal to one diameter of the shot. The body is of cast iron.

An axial cavity, bored from the base, runs nearly the whole length of the projectile. Into this cavity melted lead is poured and allowed to cool, after which the shank is screwed in. The lead increases the weight of the shot without increasing its volume.

Dimensions.

	Inches.		Centim'rs.
Total length	15.0	=	38.090
Length of ogival head	1.73	=	4.3942
Radius of head	2.0	=	5.080
Length of cylindrical part	12.27	=	31.1148
Diameter of cylindrical part	2.0	=	5.080
Length of frustum	1.0	=	2.540
Diameter of smaller base of frustum	1.375	=	3.4925
Axial cavity—Total length	13.5	=	34.289
Length filled with lead	12.0	=	30.479
Diameter	1.0	=	2.540
Shank—Total length	6.5	=	16.510
Length of screw-thread	1.5	=	3.810
Diameter (exterior) of screw-thread	1.1	=	2.794
Length from plane of base	5.0	=	12.700
Distance from base to center of eye-hole	4.5	=	11.430
Diameter of eye-hole	.4	=	1.016
Width at eye	1.0	=	2.54
Thickness at eye	.4	=	1.016
Diameter of neck	.5625	=	1.42875
Distance of center of gravity from base	7.0	=	17.78

Weight.

	Lbs.		Kilos.
Weight, a little more	13	=	5.896

3. 3-INCH PROJECTILE.

Diameter, 3 inches = 7.62 centimeters.

(Plate XI.)

This is an elongated, solid, cast-iron smooth-bore projectile. In form it is cylindro-ogival, with a frustum of a cone for its base.

The radius of the ogival head is equal to the diameter of the shot.

The edges or angles about the base are slightly rounded.

A *shank*, or eye-bolt, of wrought iron is screwed into the base of the projectile to serve as a point of attachment for the shot-line.

Dimensions.

	Inches.		Centim'rs.
Total length	13. 8	=	35. 051
Length of ogival head	2. 6	=	6. 604
Radius of head	3. 0	=	7. 620
Length of cylindrical part	9. 9	=	25. 146
Diameter of cylindrical part	3. 0	=	7. 620
Length of frustum	1. 3	=	3. 302
Diameter of smaller base of frustum	1. 7	=	4. 318
Shank—Total length	6. 5	=	16. 510
Length of screw	1. 5	=	3. 810
Diameter of screw	1. 0	=	2. 540
Length from plane of base	5. 0	=	12. 700
Distance from base to center of eye-hole	4. 5	=	11. 430
Diameter of eye-hole	. 4	=	1. 016
Width at eye	1. 0	=	2. 540
Thickness at eye	. 4	=	1. 016
Diameter of neck	.625	=	1. 5875

Weight.

	Lbs.		Kilos.
Weight about	23	=	10. 432

III. GUN-CARRIAGES.

The carriages or beds for these guns are shown in the accompanying drawings, which are sufficiently explanatory. The cheeks and front transom are of wood, and all other parts are made of metal; wrought iron in the two already made.

WEIGHTS.

1. *Carriage for 2.5 and 3 inch guns.*

(Plate XXVII.)

	Lbs.	Kilos.
For gun C, carriage and quoin	54.25	= 24.607+
For gun C, carriage alone (49.41 lbs.), say	50.0	= 22.68

2. *Carriage for 2-inch gun—(Gun B).*

(Plate XXVI.)

	Lbs.	Kilos.
Weight of carriage and quoin	35.0	= 15.876
Weight of carriage alone	33.5	= 15.196

IV. FAKING-BOXES.

Faking-box A should be used for lines Nos. 6 and 7.
Faking-box B, for braided lines Nos. 4 and 4½.
Faking-box C, for braided line No. 5.
Faking-box D, for braided line No. 3½.

V. SHOT-LINES.

The Silver Lake Company's braided linen lines, Nos 3½, 4, 4½, 5, 6, and 7, should be preferred. No. 3½ is advisable where extreme range is required. The others may be used in ordinary cases. The "water-proof finish" should be required.

VI. IMPLEMENTS, &c.

The following list of minor implements and articles should go with each gun:

LIST.

Sponge and rammer.
Wiping-rod and wiper.
2 priming wires.
Lanyard.
Combination level.
Gunner's haversack.
Cartridge bags, two sizes.
Friction primers.
Quick match for 2″ gun.

VII. SERVICE CHARGES OF POWDER (ORDINARY).

1. For 2″.5 gun.		2. For 2″ gun.	
Number of line.	Weight of powder.	Number of line.	Weight of powder.
	Ounces.		*Ounces.*
3½	4 to 6	3½	3 to 4
4 and 4½	4 to 6	4 and 4½	3 to 4
6 and 7	4 to 8	5, 6, and 7	3 to 6

3. For drills, 3 ounces should be used.

CHAPTER III.

I. INSTRUCTIONS.

Keep the bore of the gun clean at all times. There is often a deposit left after firing, near the seat of the charge, which prevents the projectile from going entirely down to the cartridge. This deposit should always be removed.

The projectiles should be kept free from rust. The use of emery cloth and the application of a little oil will protect the shot from rust.

In loading, always measure the distance from the charge to the muzzle with the ramrod or wiper and apply it to the shot; in this manner the gunner can always tell whether the projectile is fully down or is obstructed by dirt or sand.

If the piece be fired when the projectile is not "home," it strains the gun unnecessarily.

II. DIRECTIONS FOR FIRING.

Having the gun and apparatus on the ground, to prepare for firing:

1. Select a place where the gun and carriage may recoil without striking rocks or other obstructions.
2. Note the position of the vessel to be relieved, her distance from the shore, the direction and approximate force of the wind.
3. Place the gun in position, making allowance for the force of the wind and for the drift of the line.
4. Place the faking-box and line on the windward side of the gun, and two or three feet from it, not more. The box should be on a line with the muzzle of the gun. Loosen the hasps, invert the box, and incline it to the front at an angle of about 45°.
5. See that the vent is clear by inserting the priming-wire.
6. Wipe off the shot with care, freeing it from dirt and sand.
7. Remove the frame and faking-pins, pressing at the same time gently upon the "false" bottom to keep the fakes in place. Then remove the "false" bottom by lifting it slowly until clear of the box.
8. Seize the end of the line, drawing out just enough to reach to the gun without disturbing the fakes in the box, pass the end through the eye-hole in the shank and tie two or three half hitches in it, drawing the knot down close to the eye; then wet about three or four feet of the line.

[The wetting is a precaution that was not taken in the experimental firing, it not being found necessary. It is better, however, to err on the safe side.]

9. Remove the tompion or muzzle cover from the piece.
10. Insert the cartridge.
11. Insert the projectile slowly until it rests upon the cartridge.
12. Prick the cartridge with the priming wire to avoid disturbing the elevation after being given.
13. Set the "combination level" to the desired angle.
14. Place the lower arm of the level lengthwise upon the chase.
15. Elevate the muzzle until the bubble of the level stands at the middle of the tube.
16. Adjust the quoin.
17. Unroll the lanyard and insert the hook in the wire loop of the friction primer.

18. Insert the primer gently in the vent.
19. Stand clear of the line.
20. Fire the piece.

NOTE. If any of the fakes should slide from the box to the ground, place the loose line in small fakes not more than 18 inches long in front of the box. The necessity for this operation should be avoided if possible.

III. MANNER OF FAKING.

Faking is an operation which requires some care. Any person may learn to do it in a kind of way, but it requires a man who can exercise a little common sense to do it well. Carelessness and ignorance are the most fruitful causes of want of success in laying up lines by this method. Practice alone can make a successful "faker." One man *may* fake a line, but, having to attend to three operations at the same time, does none of them properly. Two men may put up a line, but, as before, there being more operations than men they often fail. Three men *can* fake a line well. For convenience of reference, I will number these men Nos. 1, 2, and 3. Their duties will be given here consecutively, but it must be understood that they are performed simultaneously.

Duties of No. 1.

No. 1 is the "faker," and is responsible for the condition in which the line is stowed away. He takes the faking-box, places it on the ground with the side or top uppermost, puts the frame with the pins on top of it, seizes the "false" bottom and lowers it into position over the pins, and stands at the side facing the box. He is now ready to begin faking. The cord or line is supposed to be on the same side of the box as the "faker," and at some distance in rear of him, in coils or upon an improvised reel.

No. 2 stands on the opposite side of the box from No. 1 and facing him.

No. 3 is about 2 yards behind No. 1, and stands ready to pay out the line from the reel or coil.

No. 1 seizes the end of the line, with his right hand draws it forward letting it pass close to his right side, lays the end along the "false" bottom with the end to his right. [It was formerly the custom to coil several yards of line loosely upon the "false" bottom before beginning to fake; this should not be done; no more line should be put on the bottom than just sufficient to reach the length of the box, as that length will generally be sufficient to reach from the box to the gun in loading, thus avoiding long fakes on the ground and the disturbance of the fakes in the box.] He then leads the line between the corner and second pins at the left-hand corner of the frame, on the side of No. 2, brings it around the corner pin and between the second and third pins in the end row, thence diagonally across the corner and around the second pin of the side row from left to right (No. 2 holds down this loop), thence back and around third pin of the end row (holding down this loop with the thumb and finger of his left hand); this forms the first fake in the first tier. Repeating this operation he forms a tier of diagonal fakes and brings up at the right-hand corner on his own side of the box, and passing the line around the second and corner pins of the end row (on the right) between the corner and second pins on the side row next to him, he carries the line along the length of the box, and out between the corner and second pins in the left-hand end row, and around the corner and second pin in the row on the side towards him, thence across

the corner and around the second pin in the end row, then back around the third pin in the side row, forming the first fake of the second tier.

The second tier will end at the right-hand corner on the side opposite the faker, when the line is carried in a similar manner along the frame on the side of No. 2 to the left-hand corner on that side, where the third tier begins.

Thus, it will be seen that the odd numbers of tiers begin at the left-hand corner on the side opposite to the faker, while the second, fourth, sixth, &c., or even numbers of tiers begin always at the left-hand corner on the side upon which the faker stands.

No. 1 continues this operation of faking with his right hand and holding down the loops nearest to him with his left until the pins are filled, then if any line be left unfaked he coils it loosely on top of the tiers and passes the end down on one side to the notch in the "false" bottom.

Nos. 1 and 2 take hold of the frame, one at each end, lift it off the box and place it on the ground.

No. 3 seizes the box and inverts it over the faking-pins and line, with the notched side over the loose end of line, which is allowed to extend out for about a foot. No. 1 holds this end in the notch of the "false" bottom until the box is adjusted in position, when Nos. 2 and 3 close and fasten the hasps. The box and line are now ready for transportation.

Duties of No. 2.

No. 2 takes his place opposite to No. 1, the box with the faking-pins being between them. His duty is to press down and hold the loops in place on his side of the frame as fast as No. 1 passes them over the pins; when the faking is completed he assists No. 1 in moving the frame and line from the box to the ground, and fastens the hasp at one end of the box.

Duties of No. 3.

The position of No. 3 is about 6 feet or less in rear of No. 1. He pulls the line from the reel (which may be mounted upon a temporary stand or frame) or coil, disentangles it, removes all knots or kinks, and pays it out to No. 1, who fakes it up. The ease and rapidity with which No. 1 fakes will depend greatly upon the manner in which No. 3 pays out the line. If he does not give enough slack, No. 1 will draw the fakes too tightly around the pins, bending and drawing them together at the top, bringing unnecessary strain upon the frame, and in exceptional cases bending the frame so much that the hasps cannot be fastened. The same effect will be produced if No. 3 permits too much slack, as then the extra weight and effort causes No. 1 to wind too tightly. No. 3 must obey the directions of No. 1 in paying out line, and accommodate himself to the rapidity of action of the faker. Strict attention and frequent practice are necessary to acquire any degree of skill in this manipulation. No. 1 has the tedious and tiresome part to perform in this operation. He must be especially careful not to draw the loops too tightly around the pins; this he unconsciously will be sure to do without the exercise of great caution. He should instruct No. 3 in regard to the rapidity of passing the line. When faking, he should always leave the fakes as loose upon the pins as he thinks is necessary, and then leave them a little looser.

It is almost impossible for one man to fake a line without drawing it too tight, besides which it is a long and toilsome process. Two men can do it but little better, since No. 2 can render No. 1 no assistance in

drawing the line from the reel or coil. Three men should always be employed when possible. Practice, and a great deal of it, alone can make an expert faker.

Intelligent instruction by illustration should be given to new men until they thoroughly understand the method, for faulty customs and habits when formed are not easily corrected.

Frequent drills in faking should be maintained by the keepers of stations, during which all the surfmen should be taught, not only how to fake, but how to do it well and rapidly.

An ordinary faker with two *good* assistants can put up 600 yards of No. 7 line in from 25 to 28 minutes. A clumsy man will generally be from 40 to 50 minutes putting up the same line.

It must be remarked, however, that the more rapid the faking the greater the danger of getting it too tight upon the pins.

IV. CONCLUSION.

In the use of this, as of all other apparatus, a certain degree of care and common sense must be constantly exercised by those who have it in charge. The best and most perfect apparatus in the world will prove a miserable failure in the hands of ignorance and carelessness. The necessity for thorough instruction and frequent practice is nowhere so urgently called for as in the fitting of men to handle efficiently the appliances for saving human life.

PART II.

CHAPTER I.

BRONZE LIFE-SAVING GUNS.

The term "life-saving guns" is here used to designate such ordnance as may be employed to effect communication between stranded vessels and the shore, by throwing a projectile carrying a line from the shore over a vessel, or from a vessel to the shore.

The guns and mortar treated of in this chapter are given in the chronological order of their preparation for experimental firing.

SECTION I. RIFLED MORTARS.

3-INCH MUZZLE-LOADING RIFLED MORTAR.

(Plate I.)

DESCRIPTION.

This piece is made from an old bronze gun which was found among a lot of captured ordnance. The gun is of an obsolete pattern and its history is unknown. It was prepared under the direction of "The Ordnance Board," United States Army, for making experiments in connection with the United States Life-Saving Service.

The muzzle was cut off 5″.4 from the trunnions, and a muzzle-band or cylindrical (exterior) ring 5″ in length screwed on as shown in the plate (Plate I, Fig. 1).

The rifling consists of 3 grooves, 0″.75 wide and 0″.1 deep. The grooves begin 1″.25 in front of the chamber and reach their full depth at 2″ from the same plane.

The ramp, joining the surfaces of the bore and the bottom of the grooves, is 0″.75 in length.

The grooves are rectangular in section, with the corners slightly rounded. The exterior tapers slightly from the base ring to the trunnions. The old vent had been filled up and a new one with a copper bouche inserted.

The axis of the trunnions is below that of the piece. The chamber is cylindro-spherical.

Dimensions.

Total length	26.25 inches.
Total length of bore, including chamber	20.25 inches.
Diameter of base ring	6.2 inches.
Diameter in rear of trunnions	5.1 inches.
Diameter at vent	5.7 inches.
Diameter in front of chamber	5.65 inches.
Diameter at muzzle	5.35 inches.
Diameter of bore	3.0 inches.
Diameter of chamber	2.5 inches.
Total length of chamber	2.75 inches.
Length of cylindrical part of chamber	1.50 inches.

Radius of bottom of chamber	1.25 inches.
Length of trunnions	1.9 inches.
Diameter of trunnions	2.0 inches.
Thickness of metal at vent	1.6 inches.
Thickness of metal in front of chamber	1.32 inches.
Thickness of metal at muzzle	1.1 inches.
Distance of vent from bottom of chamber	1.5 inches.
Number of grooves	3.
Depth of grooves	0.1 inch.
Width of grooves	0.75 inch.
Twist, 1 turn in 10 feet.	
Vent piece, diameter of screw	0.75 inch.
Vent piece, diameter of head	0.85 inch.
Vent, diameter of	0.2 inch.

Weights, &c.

Weight of rifled mortar (converted)	133 pounds.
Preponderance	43.25 pounds.

SECTION II. SMOOTH-BORE GUNS.

Bronze was selected as the metal from which to cast the experimental guns.

The necessary calculations and drawings were made, and copies of the latter, upon tracing-linen, were placed in the hands of the South Boston Iron Company, who had undertaken the fabrication of the guns.

I. BRONZE GUN A.

Caliber, 3 inches=7.62 centimeters (converted).

(Plate II.)

In the plate this gun is represented with the diameter of the bore 2.5 inches. Later, the bore was enlarged to a diameter of 3 inches, as will be seen hereafter, though the total length of the bore remained unaltered.

The exterior of this gun is divided into four principal parts, viz, the *breech*, the *first reinforce*, the *second reinforce*, and the *chase.*

The breech is a hemisphere whose radius is equal to the semi-diameter of the first reinforce.

The first reinforce is cylindrical, and extends from the base of the breech to a point in front of the axis of the trunnions.

The second reinforce is a short frustum of a cone, joining the first reinforce to the chase. The latter is cylindrical, and is of a lesser diameter than the first reinforce.

The chase is terminated in front by the *face* of the piece without any swell of the muzzle or muzzle-band. The cascabel and trunnions are short cylinders.

The rim bases unite with the exterior surface of the gun by tangent-curved surfaces.

The vent-piece is of copper. The vent is perpendicular to the axis of the piece, and is 1.5 inches (3.81 centimeters) from the bottom of the bore.

The bore is cylindrical and is terminated at its lower extremity by a hemispherical chamber, by which term it is proposed to designate the bottom of the bore. The gun was designed for a caliber of 2.5 inches (6.35 centimeters).

When first completed, however, it was bored out to a caliber of only

2 inches (5.08 centimeters), in order to make some preliminary experiments with projectiles of that diameter. It was afterwards bored up to caliber of 2.5 inches, and a series of experiments made. Still later the size of the bore was increased to 3 inches, and half an inch was taken from the length if each trunnion.

The following table gives the respective weights of this gun after the successive operations:

Weights of bronze gun A.

	Actual weight.	Calculated weight.
	Pounds.	*Pounds.*
With bore 2″ in diameter	137	132.410+
With bore 2″.5 in diameter	127.5	122.467+
With bore 3″ in diameter	114	....

The theoretical weight was calculated upon the assumption that the specific gravity of the alloy was 8.7.

PREPONDERANCE.

With 2″ caliber, about	6	ozs. ("muzzle preponderance.")
With 2″.5 caliber	2.5	lbs.
With 3″.0 caliber	6.5	lbs.

1. Character of the bronze.

The alloy, as shown by the fracture, appeared to be very homogeneous. The action of the metal in the turning-lathe indicated great toughness. The surfaces of the specimens tested presented after fracture that peculiar blistered appearance and change of form which is usually exhibited by good bronze when subjected to great tensile strain.

This gun was cast muzzle downwards, and, consequently, the "riser" or sinking-head was in rear of the cascabel. The specimens for testing were taken from that portion of the "riser" which was nearest to the breech of the gun. They were four in number.

Three of the specimens were cut from the exterior of the "riser" equidistant from each other, measured circumferentially; the fourth was an axial specimen from the same mass of metal. (See Plate III, Fig. 1.)

The axes of all the specimens were parallel to the axis of the gun.

Screw-threads were cut upon the heads to fit them to the holders of the testing-machine.

Upon both ends of the pieces were marked the letter A to designate the gun, the letter H to indicate the sinking-head from whence they were taken, and the numbers of the specimens.

Dimensions of specimens.

Total length	6.4	inches.
Length of shoulders	0.2	inch.
Length between shoulders	4.0	inches.
Length of heads	1.0	inch.
Diameter	0.798	inch.
Area of cross-section	0.5	inch.
Diameter of heads before cutting thread	1.4	inches.
Diameter of heads after cutting thread	1.25	inches.

(See Plate III, Figs. 1, 2, and 3.

These carefully turned and finished samples of bronze were placed in the hands of Mr. C. B. Richards, engineer of the Colt's Patent Fire-Arms

Manufacturing Company of Hartford, Conn., to be tested upon the testing machine constructed by that company. This machine owes its present accuracy and general excellence to the scientific ability of Mr. Richards, under whose supervision it was constructed. In this place a mere abstract of the results of the tests will be given; for further detailed information in regard to the tests and the machine reference must be made to the report of Mr. Richards, which will be found upon subsequent pages.

Tests of metal in bronze gun A.

Test-number of the specimen		912.	913.	914.	915.
Original mark on the end of the specimen		A. H. 1.	A. H. 2.	A. H. 3.	A. H. 4.
Original minimum diameter of the specimen		0.789	0.797	0.797	0.798
Minimum area of cross-section	Original	0.489	0.499	0.499	0.5
	After fracture	0.283	0.292	0.283	0.418
Distance between gauge-marks	Original	3.49	3.49	3.49	3.49
	After fracture	5.38	5.30	5.38	3.95
Greatest observed stress sustained without set		5500.	6000.	6000.	3500.
Breaking stress		23280.	23340.	23740.	14220.
Elastic resistance, in pounds per square inch, of original cross-section		11000.	12000.	12000.	7000.
Ultimate resistance, in pounds per square inch, of original cross-section		47600.	46780.	47580.	28440.
Greatest reduction of cross-section per cent		42.1	41.5	43.3	16.4
Ultimate elongation between gauge-marks per cent		54.1	51.6	53.9	13.3

NOTE.—Dimensions and areas are given in inches and stresses in pounds. No. 915 was the axial specimen.

"The stresses were applied gradually in all cases."

"Observations to ascertain when a permanent set was produced were made after the addition of each 500 pounds stress up to the elastic limit."

"The extensions produced by increasing the stress from 1,000 pounds to 3,000 pounds were as follows:

Test-number of specimen	912.	913.	914.	915.
Extensions ten-thousandths of an inch	11.	10.	8.5	10.
Moduli of elasticity millions of pounds	12.7	14.	16.5	14.

2. MARKS.

The only external mark upon the gun is the letter A on top of the gun between the trunnions.

3. NOMENCLATURE.

A—Breech.
B—First reinforce.
C—Second reinforce.
D—Chase.
E—Chamber.
F—Bore.
G—Trunnions.
H—Cascabel.
I—Rimbases.
V—Vent.

4. NOTATION AND DIMENSIONS.

D = diameter of first reinforce = 6.0 inches.
d_1 = diameter of chase = 4.5 inches
d_2 = diameter of bore = 2.5 inches
d_3 = diameter of trunnions = 2.5 inches
d_4 = diameter of cascabel = 2.0 inches
d_5 = diameter of rimbases, assumed to be cylinders = 3.5 inches
R = radius of breech = 3.0 inches
r = radius of chamber = 1.25 inches
r^1 = radius of chase = 2.25 inches
l_1 = length of first reinforce = 7.25 inches
l_2 = length of second reinforce = 2.0 inches.

l_3 = length of chase .... = 8.75 inches.
l_4 = length of bore exclusive of chamber .... = 16.75 inches.
l_5 = length of trunnions .... = 2.5 inches.
l_6 = length of cascabel .... = 1.5 inches.
l_7 = length of rimbases .... = 0.1 inch.
v_1, v_2, v_3, &c., = volumes of breech, first reinforce, second reinforce, &c., in cubic inches.
x_1, x_2, x_3, &c., = distances of centers of gravity of breech, first reinforce, second reinforce, &c., from plane of reference.

5. Calculations.

a. Volumes.

A. Breech—hemispherical:

Volume $= \frac{1}{2} D^3 \times .5236 = \frac{1}{2} \times 216. \times .5236 = v_1 = 56.5485 +$ cubic inches.

B. First reinforce—cylindrical:

Volume $= D^2 \times .7854 \times l_1 = 36 \times .7854 \times 7.25 = v_2 = 204.9886$ cubic inches.

C. Second reinforce—frustum of a cone:

Volume $= \frac{1}{3} l_2 \times .7854 \left(\frac{D^3 - d_1^3}{D - d_1}\right) = \frac{1}{3} . 2 \times .7854 \left(\frac{216 - 91.125}{6 - 4.5}\right) = v_3 =$ 43.59 cubic inches.

D. Chase—cylindrical:

Volume $= d_1^2 \times .7854 \times l_3 = 20.25 \times .7854 \times 8''.75 = v_4 = 139.1627$ cubic inches.

E. Chamber—hemispherical:

Volume $= \frac{1}{2} d_2^3 \times .5236 = \frac{1}{2} . 15.625 \times .5236 = - v_5 = 4.0906$ cubic inches.

F. Bore—cylindrical:

Volume $= d_2^2 \times .7854 \times l_4 = 6.25 \times .7854 \times 16.75 = - v_6 = 82.2213$ cubic inches.

G. Trunnions (2)—cylindrical:

Volume $= 2 d_3^2 \times .7854 \times l_5 = 2 \times 6.25 \times .7854 \times 2''.5 = v_7 = 24.5436$ cubic inches.

H. Cascabel—cylindrical:

Volume $= d_4^2 \times .7854 \times l_6 = 4 \times .7854 \times 1.5 = v_8 = 4.71$ cubic inches.

I. Rimbases (2)—cylindrical (assumed to be):

Volume $= 2 d_5^2 \times .7854 \times l_7 = 2 \times 12.25 \times .7854 \times 0''.1 = v_9 = 1.9242$ cubic inches.

Weight.

	Cubic inches.		Cubic inches.
$v_1 =$	56.5486	$-v_5 =$	− 4.0906
$v_2 =$	204.9886	$-v_6 =$	− 82.2213
$v_3 =$	43.5900		(−) 86.3119
$v_4 =$	139.1627		

+ 444.2899 = volume of gun less trunnions, rimbases, and cascabel.
(−) 86.3119 = volume of chamber and bore.

+ 357.9780 = volume of metal less trunnions, rimbases, and cascabel.
$v_7 =$ 24.5436 = volume of metal in trunnions.
$v_8 =$ 4.7100 = volume of metal in cascabel.
$v_9 =$ 1.9242 = volume of metal in rimbases.

$V = \Sigma(v) =$ 389.1558 = total volume of metal in gun.

$w = 0.3147$ pounds avoirdupois = weight of one cubic inch of bronze whose specific gravity is 8.7.

Hence $W = V \times w = 389.1558 \times .3147$ pound $= 122.467 +$ pounds = weight of gun.

b. Center of gravity.

Assuming the plane YZ, the plane of reference, to coincide with the base of the breech, and the axis of X to coincide with the axis of the bore, then, since the volume is symmetrically disposed in regard to this axis, the center of gravity of the gun will be given by the formula—

$$x = \frac{v_1 x_1 + v_2 x_2 + v_3 x_3 + \&c.}{v_1 + v_2 + v_3 + \&c.}$$

in which

$x =$ the distance of the center of gravity of the gun from the plane of reference, and

v_1, v_2, &c. = the elementary volumes;

x_1, x_2, &c. = the distances of their respective centers of gravity from the plane of reference.

All distances estimated towards the right from the plane YZ are regarded as positive; all estimated towards the left from this plane are regarded as negative.

The volumes of all cavities (such as bore, chamber, &c.) are considered as negative.

The volumes of the trunnions and rimbases are omitted in this computation, since they are symmetrically disposed about a line passing through the center of gravity of the gun, and perpendicular to the axis of the gun.

The cascabel is also omitted on account of its small size and weight.

COMPUTATION.

Values of x_1, x_2, x_3, &c.

For—

A. Breech—hemisphere:

$$(-)\ x_1 = \tfrac{3}{8} R = \tfrac{3}{8} . 3'' = -1''.125.$$

B. First reinforce—cylinder:

$$x_2 = \tfrac{1}{2} l_1 = \tfrac{1}{2} . 7''.25 = 3''.625.$$

C. Second reinforce—frustum of cone:

$$x_3 = 7''.25 + \tfrac{1}{4} . l_2 \left(\frac{3 r'^2 + 2 Rr' + R^2}{R^2 + Rr' + r'^2}\right)$$

$$= 7''.25 + \tfrac{1}{4} . 2'' \left(\frac{15.1875 + 13.50 + 9}{9 + 6.75 + 5.0625}\right)$$

$$= 7''.25 + 0''.9054$$

$$\therefore x_3 = 8''.1554$$

D. Chase—cylinder:

$$x_4 = 9''.25 + \tfrac{1}{2} l_3 = 9''.25 + 4''.375 = 13''.625.$$

E. Chamber—hemisphere:

$$x_5 = 1''.25 - \tfrac{3}{8} r = 1''.25 - .''46875 = 0''.78125.$$

F. Bore—cylinder:

$$x_6 = 1''.25 + \tfrac{1}{2} l_4 = 1''.25 + 8''.375 = 9''.625.$$

Substituting the values of v_1, v_2, &c., and x_1, x_2, &c., in eq., and multiplying, we have—

$$x = \frac{(-63.61735 + 743.0844 + 355.4901 + 1896.0870 - 3.19577 - 791.38)}{56.5485 + 204.9886 + 43.59 + 139.1627 - 4.0906 - 82.2213}$$

or

$x = 5''.968155$, say $x = 5''.97$ = distance of center of gravity of gun from the plane of reference.

6. Fabrication of experimental bronze gun A.

1. *Drawing.*—A full size drawing of the gun was first made; the dimensions in inches and decimal parts of an inch were marked upon this drawing. An accurate copy of this drawing was made upon tracing-linen and sent to the South Boston Iron Company to guide the founder.

2. *Drawing for the chills.*—The manufacturers prepared a full-size drawing of a set of iron chills in which the gun was to be cast. The dimensions of the chills were such as to allow for the contraction of the metal in cooling, for finishing the gun, and for the sinking-head or "riser." The chills are made in two parts which are identical in form.

3. *Pattern.*—From the above drawing, a model or pattern of one-half of the chill was made of white pine, due allowance being made for the shrinkage of the cast iron in cooling. The model was completed by smoothing it off with sand-paper and varnishing.

4. *Molding.*—From this half-model a mold of one of the half-chills was formed in wooden flasks. This was done by ramming molding-composition compactly around the mold. This composition is a kind of sandy loam, containing just enough clay to make it cohesive when slightly moistened and pressed together. The wooden half-flasks are kept from sticking together by being sprinkled with a dry white sand, called *parting-sand* by molders. The mold for the second half-chill was made in the same manner. The molding being completed, the half-flasks were bolted together, and placed in an oven to dry thoroughly.

5. *Casting the chills.*—When perfectly dry, the flasks containing the molds were removed from the oven, the cast iron was melted and run into them. After cooling, the flasks were removed and the chills were prepared to receive the bronze casting for the gun.

6. *The chills.*—(Fig. 1, plate 47.) These were of cast iron, 1″.75 thick. The total length was 13″ greater than the extreme length of the gun. Of this surplusage, one inch was on the muzzle end, and 12″ at the breech for a sinking-head or "riser." The cavity at the breech end was cylindrical, 6″.5 in diameter; that at the muzzle was a frustum of a cone whose lesser base had a diameter of 5″. The faces of the flanges where the half-chills came together were planed in order to fit closely. The half-chills were bolted together and the bottom closed by an iron plate, 1″.75 thick, bolted to the bottom flange.

7. *Heating the chills.*—The inside surfaces of the chills were coated with clay-wash and placed in an oven to dry and become heated before pouring the melted metal for the gun, in order that the exterior should not cool too rapidly. This clay-wash is made by mixing three parts of ground fire-brick with one part of German or English fire-clay, and adding a sufficient quantity of water. When nearly ready to cast the gun, the chill was removed from the oven and taken to a place near the furnaces where the crucibles were heating. A "clay mold," 6″ in length, whose interior diameter was also 6″, was added to the height of the sinking-head in order to avoid getting cinders in the metal near the breech of the gun. The chills were so made that the gun was cast muzzle downwards.

8. *The furnaces.*—(Fig. 2, plate 47.) These were iron cylinders about 3′ high, and 2′ in diameter, lined with fire-brick. They are technically called "pots." A high chimney furnished the draught. The gun being a small one, it was unnecessary to use a reverberatory furnace, since three crucibles (Fig. 3, plate 47) would hold the requisite amount of metal. The crucibles were placed in the "pots" and the metals for the alloy melted without difficulty. The fuel used was Lehigh coal with

broken charcoal put over the metal in the crucibles. The condition of the furnaces or "pots" was such that only two of those in the new foundery could be used. The third crucible had to be heated in a "pot" about forty yards from the others. The isolated "pot" had a less efficient chimney.

9. *Charging the crucibles.*—The metals used were Lake Superior copper and German tin. Both of these metals were in the form of ingots. The copper ingots weighed from 12 to 13 pounds each. The metals were carefully weighed and placed in the crucibles as stated in the table given below. The tin was removed when the crucibles were placed in the furnace and added subsequently. The proportions of the two metals used were as follows:

Copper	92 per cent.
Tin	8 per cent.

The calculated charge was:

Copper	333.96 lbs.
Tin	29.04 lbs.
Total	363.00 lbs.

Actual charges.

Metal.	In crucible—			Total.
	No. 1.	No. 2.	No. 3.	
	Lbs. ozs.	*Lbs. ozs.*	*Lbs. ozs.*	*Pounds.*
Copper	120 00	120 00	94 00	334
Tin	10 7	10 7	8 2	29
Total charge				363

10. *Time of melting, &c.*—The fires were lighted under all the crucibles at 11 a. m. The copper in Nos. 1 and 2 was all melted at 3.15 p. m., while that in No. 3, though a less charge, was not melted on account of a defective draught or some other cause. This necessitated the holding back of Nos. 1 and 2. The charge of No. 3 was finally melted at 4 p. m. On examination it was found that the metal in No. 2 was not quite hot enough. At 4.15 p. m. the tin was added to the melted copper in the crucibles. The ingots of tin were immersed in the melted copper and stirred up thoroughly as it melted to prevent oxidation.

11. *Casting.*—When ready for casting, crucible No. 3 was lifted from the "pot" and carried through the open air to the room where Nos. 1 and 2 were situated. The pouring ladles were (Fig. 4, plate 47) at hand, filled with burning charcoal to keep them hot. When all was ready, crucible No. 3 was emptied into ladle No. 1, but not filling it, crucible No. 1 was hoisted out and the ladle filled from it. Ladle No. 2 was then filled with what remained in crucible No. 1 and the contents of No. 2. As soon as both ladles were ready, their contents were, in succession, poured directly into the chills, filling the cavity to the top. The gun was cast at 4.40 p. m. From unskillful manipulation a good many cinders and a good deal of scoria found a passage into the chills. The casting was taken from the chills at 7 to 7.30 a. m. the next morning, and weighed, in a rough state, 363 pounds with the riser. The above weight, 363 pounds, was given by Mr. Reed, the superintendent in charge of the foundery. This first casting was made on October 1, 1877. When the gun came to be turned, it was discovered that the

metal or alloy had not been hot enough when poured, and that charcoal cinders had entered with the molten metal and appeared all along the chase and breech. This casting was rejected. An attempt was now made to prepare a runner-box or receptacle for the metal which should be self-skimming. This was accomplished by placing on top of the sand flask a runner-box having near one side a 2″ hole pierced through the bottom to allow the liquid metal to pass, and on the other side a cup or bowl into which this metal was first poured. A partition a few inches in height separated the two compartments.

Second casting.

Mode of pouring.—The runner-box being placed in position upon the flask, the melted metal, in ladles, was then poured, at first slowly, into the cup-shaped receptacle until it rose to the top of the partition and ran over it. The partition was intended to arrest the scoria in the first instants of the casting until enough metal ran over to fill the two-inch hole and rise above it a sufficient distance to preclude any chance of the scoria or cinders getting through the bottom orifice. When the operation had proceeded thus far, all that was necessary was to pour fast enough to keep the metal from falling so low as to permit the residuum to pass before the flask was filled.

Notwithstanding these precautions enough cinders passed into the chills and lodged in the trunnion holes on top (in rear of) of the trunnions to reject this casting also. It was then decided to cut away 0″.375 of the metal in the chills in rear of the trunnions where this lodgment had occurred. This would allow a small lodgment of cinders, &c., without injuring the soundness of the casting.

A third and successful trial was then made. Below are given the charges and dates of the recastings, and a *résumé* of the first trial.

First casting.

Date: October 1, 1877.

	Pounds.
Charge: Copper	334
Tin	29
Total	363

Weight of rough casting 363 pounds (Reed).

Second casting.

Date: October 4, 1877.

Charge: First casting, weight 363 pounds.
No metal used except the previous casting.

Third casting.

Date: October 8, 1877.

	Pounds.
Charge: Metal from second casting	319
Copper, ingot	17
Tin, ingot	2.9
Total charge	338.9
Weight of rough casting	329
Weight of finished gun bored out to 2 inches caliber	137

Of the 2.9 pounds of tin added to the charge for this casting, 1.4 pounds was the proportion to be added to the 17 pounds of new copper, and 1.5 pounds was about one-half of 1 per cent. of the weight of metal used from second casting. This was added to supply the amount of tin assumed to be lost by oxidation in the two previous castings.

In the third trial the fire was lighted at 10.30 a. m.; metal all melted at 2.30 p. m.; tin added at 2.30 p. m.; gun cast at 3 p. m.

The gun was turned, bored, and finished in the usual manner.

II. BRONZE GUN B.

Caliber: 2 inches = 5.08 centimeters.

(Plate IV.)

This gun is of the same general form as gun A, but is much smaller and lighter. It also was made by the South Boston Iron Company. This piece was cast in chills, muzzle downward, and finished in a similar manner to gun A. The cast-iron chill was 4 inches longer than the length of the gun including the cascabel. A clay mold 8 inches in length was added above the chill to increase the height of the "riser," or sinking-head.

Details of casting.

Date: January 11, 1878.

	Pounds.
Charge of metal	160
Lake Superior copper, 92 per cent	147.2
German tin, 8 per cent	12.8
Total	160.0

Fire lighted in furnace at	8.30 a. m.
Copper charged	9.30 a. m.
Copper melted	1.30 p. m.
Tin added	2.00 p. m.
Gun cast	2.45 p. m.

Weights.

	Pounds.
Weight of rough casting	156.00
Weight of "riser"	40.25
Weight of gun-casting	115.75

Weight of gun.

Specific gravity of alloy, assumed	8.7	pounds.
Theoretical weight of gun	53.279+	
Actual weight of gun	54.25	
Preponderance	1.0	

1. Specimens for testing.

(Plate III, Figs. 2, 3, and 4.)

These were four in number, as in the preceding case, and were taken from the "riser" or sinking-head, just in rear of the cascabel. They were of the same size and form, and occupied the same relative positions in the casting as did the specimens from gun A. The heads of each speci-

men were marked with the letters B and H, together with its serial number; No. 4, as in the previous instance, being the number of the axial specimen. The letter B was cut on the top of the gun, between the trunnions.

Below will be found a tabulated statement of the results obtained by the testing-machine. These tests were made by Mr. Richards, engineer of the Colt Company. For further details see his appended report.

Tests of metal from sinking-head of bronze gun B.

Test-number of specimen		937.	938.	939.	940.
Original mark		B. H. 1.	B. H. 2.	B. H. 3.	B. H. 4.
Diameter of minimum cross-section	Original	0.798	0.798	0.798	0.798
	After fracture	0.66	0.67	0.665	0.73
Area of minimum cross-section	Original	0.500	0.500	0.500	0.500
	After fracture	0.342	0.352	0.347	0.418
Distance between gauge-marks	Original	3.50	3.50	3.50	3.50
	At instant of fract'e	4.69	5.02	4.95	4.07
Greatest observed stress sustained without set		6000.	5500.	6500.	4500.
Breaking stress		20820.	21900.	21920.	16860.
Limit of elastic resistance		12000.	11000.	13000.	9000.
Ultimate resistance (tenacity)		41640.	43800.	43840.	33720.
Greatest reduction of cross-section	per cent	31.6	29.6	30.6	16.4
Ultimate elongation between gauge-marks	per cent	34.0	43.4	41.4	16.3

Dimensions and areas are given in inches, stresses in pounds, and resistances in pounds per square inch of the original cross-section of the specimen.

2. Nomenclature.

A—Breech.
B—First reinforce.
C—Second reinforce.
D—Chase.
E—Chamber.
F—Bore.
G—Trunnions.
H—Cascabel.
V—Vent.

3. Notation and dimensions.

D = diameter of first reinforce	=	4	inches.
d_1 = diameter of chase	=	3.5	inches.
d_2 = diameter of bore	=	2	inches.
d_3 = diameter of trunnions	=	1.75	inches.
d_4 = diameter of cascabel	=	1.5	inches.
Diameter of vent	=	0.2	inch.
R = radius of breech	=	2	inches.
r = radius of chamber	=	1	inch.
r_1 = radius of chase	=	1.75	inches.
l_1 = length of first reinforce	=	8	inches.
l_2 = length of second reinforce	=	1	inch.
l_3 = length of chase	=	9	inches.
l_4 = length of bore, exclusive of the chamber	=	17	inches.
l_5 = length of trunnions	=	1.5	inches.
l_6 = length of cascabel	=	1.5	inches.

v_1, v_2, v_3, &c., = volumes of breech, first reinforce, &c., in cubic inches.

x_1, x_2, x_3, &c., = distances of centers of gravity of breech, first reinforce, &c., from plane of reference.

4. Calculations.

a. Volumes.

A. Breech—hemispherical:

Volume $= \frac{1}{2} D^3 \times .5236 = \frac{1}{2} .64 \times .5236 = v_1 = 16.7552$ cubic inches.

B. First reinforce—cylindrical:

Volume $= D^2 \times .7854 \times l_1 = 16 \times .7854 \times 8 = v_2 = 100.5312$ cubic inches.

C. Second reinforce—frustum of cone:

Volume $= \frac{1}{3} l_2 \times .7854 \times \left(\frac{D_3 - d_1{}^3}{D - d_1}\right) = .3333 \times .7854 \times \left(\frac{21.125}{0.5}\right) = v_3 =$ 11.0599 + cubic inches.

D. Chase—cylindrical:

Volume $= d_1{}^2 \times .7854 \times l_3 = 12.25 \times .7854 \times 9 = v_4 = 86.5903 +$ cubic inches.

E. Chamber—hemispherical:

Volume $= \frac{1}{2} d_2{}^3 \times .5236 = \frac{1}{2} .8 \times .5236 = -v_5 = 2.0944$ cubic inches.

F. Bore—cylindrical:

Volume $= d_2{}^2 \times .7854 \times l_4 = 4 \times .7854 \times 17 = -v_6 = 53.4072$ cubic inches.

G. Trunnions—cylindrical.:

Volume $= 2 \times d_3{}^2 \times .7854 \times l_5 = 2 \times 3.0625 \times .7854 \times 1.5 = v_7 = 7.2158 +$ cubic inches.

H. Cascabel—cylindrical:

Volume $= d_4{}^2 \times .7854 \times l_6 = 2.25 \times .7854 \times 1.5 = v_8 = 2.6507$ cubic inches.

Weight.

	Cubic inches.			Cubic inches.
$v_1 =$	16.7552		$-v_5 =$	$-$ 2.0944
$v_2 =$	100.5312		$-v_6 =$	$-$53.4072
$v_3 =$	11.0599			$-$55.5016
$v_4 =$	86.5903			
	214.9366	= volume of gun less trunnions and cascabel.		
	$-$55.5016	= volume of chamber and bore.		
	159.4350	= volume of metal less trunnions and cascabel.		
$v_7 =$	7.2158	= volume of metal in trunnions.		
$v_8 =$	2.6507	= volume of metal in cascabel.		
$V = \Sigma(v) =$	169.3015	= whole volume of metal in gun.		

$w = 0.3147$ pounds avoirdupois = weight of one cubic inch of bronze, whose specific gravity is 8.7.

Hence $W = V \times w = 169.3015 \times .3147 = 53.279 +$ pounds = weight of gun.

b. Center of gravity.

Assuming the plane YZ, the plane of reference, to coincide with the base of the breech, and the axis of X to coincide with the axis of the bore, then, since the volume is symmetrically disposed in regard to this axis, the center of gravity of the gun will be given by the formula—

$$x = \frac{v_1 x_1 + v_2 x_2 + v_3 x_3 + \&c.}{v_1 + v_2 + v_3 + \&c.}$$

in which

$x =$ the distance of the center of gravity of the gun from the plane of reference, and

$v_1, v_2,$ &c. = the elementary volumes;

$x_1, x_2,$ &c. = the distances of their respective centers of gravity from the plane of reference.

All distances estimated toward the right from the plane YZ are regarded as positive; all estimated toward the left from this plane are regarded as negative.

The volumes of all cavities (such as the bore and chamber) are considered as negative.

The volumes of the trunnions are omitted in this calculation, since they are symmetrically disposed about a line passing through the center of gravity of the gun, and perpendicular to the axis of the bore.

The cascabel is omitted on account of its small size. Its weight is insignificant.

COMPUTATION.

Values of x_1, x_2, x_3, &c.

For—

A. Breech—hemisphere:

$$x_1 = \tfrac{3}{8}\,R = \tfrac{3}{8}\,.\,2'' = -0''.75.$$

B. First reinforce—cylinder:

$$x_2 = \tfrac{1}{2}\,l_1 = \tfrac{1}{2}\,.\,8'' = 4''.$$

C. Second reinforce—frustum of cone:

$$x_3 = 8'' + \tfrac{1}{4}\,l_2\left(\frac{3r'^2 + 2\,R\,r' + R^2}{R^2 + R\,r' + r'^2}\right)$$

$$= 8'' + \tfrac{1}{4}.1''\left(\frac{9.1875 + 7. + 4}{4 + 3.5 + 3.0625}\right)$$

$$= 8'' + ''.25\left(\frac{20.1875}{10.5625}\right) = 8'' + 0''.4778 +$$

$$\therefore x_3 = 8''.4778 +$$

D. Chase—cylinder:

$$x_4 = 8'' + 1'' + \tfrac{1}{2}\,l_3 = 8'' + 1'' + \tfrac{1}{2}\,.\,9'' = 13''.5.$$

E. Chamber—hemisphere:

$$x_5 = 1'' - \tfrac{3}{8}\,r = 1'' - 0''.375 = 0''.625.$$

F. Bore—cylinder:

$$x_6 = 1'' + \tfrac{1}{2}\,l_4 = 1'' + \tfrac{1}{2}\,.\,17'' = 1'' + 8''.5 = 9''.5.$$

Substituting the values of v_1, v_2, &c., and x_1, x_2, &c., in equation, we have—

$$x = \frac{(16.7552 \times -0''.75) + (100.5312 \times 4'') + (11.0599 \times 8''.4778) + (86.5903 \times 13''.5) + (-2.0944 \times 0''.625) + (-53.4072 \times 9''.5)}{16.7552 + 100.5312 + 11.0599 + 86.5903 - 2.0944 - 53.4072}$$

or,

$$x = \frac{+\ 1143.6136}{+\ \ 159.435} = 7''.1729 + \text{ say } x = 7''.2 =$$

distance of center of gravity from the plane of reference.

III. BRONZE GUN C.

Caliber: 2.5 inches = 6.35 centimeters.

(Plate V.)

The exterior of this gun is divided into four principal parts, viz, the *breech*, the *first reinforce*, the *second reinforce*, and the *chase*.

The breech is a hemisphere whose radius is equal to the semi-diameter of the first reinforce.

The first reinforce is cylindrical, and extends from the base of the breech to a point in front of the axis of the trunnions.

The second reinforce is a short frustum of a cone, joining the first reinforce to the chase. The latter is cylindrical, and is of a lesser diameter than the first reinforce.

The chase is terminated in front by the *face* of the piece without any swell of the muzzle or muzzle-band. The cascabel and trunnions are short cylinders.

The rimbases unite with the exterior surface of the gun by tangent-curved surfaces.

The vent piece is of copper. The vent is perpendicular to the axis of the bore, and is 1.25 inches (= 3.175 centimeters) from the bottom of the bore.

The bore is cylindrical, and is terminated at its lower extremity by a hemispherical chamber, by which term it is proposed to designate the bottom of the bore.

1. Details of casting.

This gun was cast in the chill made for casting gun A.

Three castings were made before a satisfactory gun ingot was obtained.

First casting.

Date: March 23, 1878.

	Pounds.
Charge of metal	350
Lake Superior copper 90 per cent	315
German tin 10 per cent	35
Total	350

Fire lighted in furnace at	6.30 a. m.
Copper charged	7.00 a. m.
Copper melted	9.30 a. m.
Tin added	9.55 a. m.
Gun cast	10.40 a. m.
Amount of coal used	250 pounds.

Three crucibles were used in melting the charge: two "No. 60" crucibles, containing 99 pounds of copper and 11 pounds of tin, each; and one "No. 70," containing 117 pounds of copper and 13 pounds of tin.

Weights.

	Pounds.
Weight of rough ingot	347
Weight of "riser"	117
Weight of rough casting	230

This ingot was rejected on account of being porous at the breech.

Second casting.

Date: March 28, 1878.

	Pounds.
Charge of metal from former casting	345
Weight of rough ingot	338

Casting rejected, porous around trunnions.

Third casting.

Date: March 30, 1878.

	Pounds.
Charge of metal from preceding casting	338
Lake Superior ingot copper	13.5
German tin, ingot	1.5
Total charge	353.0
Fire lighted in furnace at	7 a. m.
Copper charged at	8 a. m.
Copper melted at	11 a. m.
Gun cast at	11.30 a. m.

Weights.

	Pounds.
Weight of rough casting	347
Weight of finished gun	108.25
Preponderance	1.5

A few spots of tin showed on the exterior surface of the gun just in front of the right trunnion.

This gun is marked with the letter C on its upper surface between the trunnions.

2. Specimens for testing.

(Plate III, Figs. 2, 3, and 5.)

The specimens for testing were similar to those for the preceding guns. The marks on the heads of the specimens are given in Fig. 5, Plate III.

For details of the tests in this case, see appended report of Mr. C. B. Richards.

3. Nomenclature.

A—Breech.	F—Bore.
B—First reinforce.	G—Trunnions.
C—Second reinforce.	H—Rimbases.
D—Chase.	I—Cascabel.
E—Chamber.	V—Vent.

4. Notation and dimensions.

D = diameter of first reinforce = 5.5 inches.
d_1 = diameter of chase = 4.5 inches.
d_2 = diameter of bore = 2.5 inches.
d_3 = diameter of trunnions = 2 inches.
d_4 = diameter of rimbases [true diameter = 2″.8], assumed 3 inches.
d_5 = diameter of cascabel = 1.5 inches.
R = radius of breech = 2.75 inches.
r = radius of chamber = 1.25 inches.
r' = radius of chase = 2.25 inches.
l_1 = length of first reinforce = 8.50 inches.
l_2 = length of second reinforce = 2 inches.
l_3 = length of chase = 9.5 inches.
l_4 = length of bore exclusive of the chamber = 18.75 inches.
l_5 = length of trunnions = 2 inches.
l_6 = length of rimbases = 0.1 inch.
l_7 = length of cascabel = 1.5 inches.

v_1, v_2, v_3, &c., = volumes of breech, first reinforce, second reinforce, &c., in cubic inches.

x_1, x_2, x_3, &c., = distances of centers of gravity of breech, first reinforce, second reinforce, &c., from plane of reference.

5. CALCULATIONS.

a. Volumes.

A. Breech—hemispherical:

Volume $= \frac{1}{2}$ D$^3 \times .5236 = \frac{1}{2}$ $166.375 \times .5236 = v_1 = 43.557$ cubic inches.

B. First reinforce—cylindrical:

Volume $=$ D$^2 \times .7854 \times l_1 = 30.25 \times .7854 \times 8.''5 = v_2 = 201.9458$ cubic inches.

C. Second reinforce—frustum of cone:

Volume $= \frac{1}{3} l_2 \times .7854 . \left(\frac{D^3 - d_1^3}{D - d_1}\right) = .6666 \times .7854 \times 75.25 = v_3 = 39.401$ cubic inches.

D. Chase—cylindrical:

Volume $= d_1^2 \times .7854 \times l_3 = 20.25 \times .7854 \times 9''.5 = v_4 = 151.0916$ cubic inches.

E. Chamber—hemispherical:

Volume $= \frac{1}{2} . d_2^3 \times .5236 = \frac{1}{2} . 15.625 \times .5236 = - v_5 = 4.0906 +$ cubic inches.

F. Bore—cylindrical:

Volume $= d_2^2 \times .7854 \times l_4 = 6.25 \times .7854 \times 18''.75 = - v_6 = 92.0391 +$ cubic inches.

G. Trunnions (2)—cylindrical:

Volume $= 2 . d_3^2 \times .7854 \times l_5 = 2 \times 4 \times .7854 \times 2''. = v_7 = 12.5664$ cubic inches.

H. Rimbases (2)—assumed cylindrical:

Volume $= 2d_4^2 \times .7854 \times l_6 = 2 \times 9 \times .7854 \times 0''.1 = v_8 = 1.4137 +$ cubic inches.

I. Cascabel—cylindrical:

Volume $= d_5^2 \times .7854 \times 1.''5 = 2.25 \times .7854 \times 1.5 = v_9 = 2.6507 +$ cubic inches.

Weight.

Cubic inches.	Cubic inches.
$v_1 =$ 43.5570	$- v_5 =$ 4.0906
$v_2 =$ 201.9458	$- v_6 =$ 92.0391
$v_3 =$ 39.4010	— 96.1297
$v_4 =$ 151.0916	
$v_7 =$ 12.5664	
$v_8 =$ 1.4137	
$v_9 =$ 2.6507	

\+ 452.6262 = total volume of gun.
— 96.1297 = volume of bore and chamber.

$V = \Sigma (v) = 356.4965$ = total volume of metal in gun.

$w = 0.3147$ pound avoirdupois = weight of one cubic inch of bronze whose specific gravity is 8.7.

Hence, $V \times w = 356.4965$ cubic inches $\times 0.3147 = 112.1896 +$ pounds = weight of gun.

b. Center of gravity.

Making the same assumptions and using the same notation, and, in addition, omitting the volumes of the rimbases, the center of gravity is found in a similar manner to that of gun B.

COMPUTATION.

Values of x_1, x_2, x_3, &c.

For—

A. Breech—hemisphere:

$$x_1 = \tfrac{3}{8}\,R = \tfrac{3}{8}.\,2''.75 = -\,1''.03125.$$

B. First reinforce—cylinder:

$$x_2 = \tfrac{1}{2}.\,l_1 = \tfrac{1}{2}\,.\,8''.5 = 4''.25.$$

C. Second reinforce—frustum of cone:

$$x_3 = 8''.5 + \tfrac{1}{4}\,l_2\left(\frac{3\,r'^2 + 2\,Rr' + R^2}{R^2 + Rr' + r'^2}\right) =$$

$$= 8''.5 + \tfrac{1}{4}.2''.0\left(\frac{15.1875 + 12.375 + 7.5625}{7.5625 + 6.1875 + 5.0625}\right) =$$

$$= 8''.5 + 0''.5\left(\frac{35.1250}{18.8125}\right) = 8''.5 + 0''.9335 = 9''.4335 +$$

$$\therefore\ x_3 = \quad 9''.4335 +$$

D. Chase—cylinder:

$$x_4 = 8''.5 + 2''.0 + \tfrac{1}{2}\,l_3 = 8''.5 + 2''.0 + \tfrac{1}{2}\,.\,9''.5 = 15''.25.$$

E. Chamber—hemisphere:

$$x_5 = 1''.25 - \tfrac{3}{8}\,r = 1''.25 - 0''.46875 = 0''.78125.$$

F. Bore—cylinder:

$$x_6 = 1''.25 + \tfrac{1}{2}\,.\,l_4 = 1''.25 + \tfrac{1}{2}\,.18''.75 = 10''.625.$$

Substituting the values of v_1, v_2, &c., and x_1, x_2, &c., in the general formula, we have—

$$x_1 = \frac{(43.577 \times -1''.03125) + (201.9458 \times 4''.25) + (39.401 \times 9''.4335) + 151.0916 \times 15''.25) + (-4.0906 \times 0''.78125) + (-92.0391 \times 10''.625)}{+43.557 + 201.9458 + 39.401 + 151.0916 - 4.0906 - 92.0391}$$

or,

$$x_1 = \frac{2497.6883}{339.8657} = +\,7''.349,$$

say $x_1 = +\,7''.35$ = distance of center of gravity from the plane of reference.

CHAPTER II.

LIFE-SAVING PROJECTILES.

The experimental projectiles, both rifle and smooth bore, are numbered in one series corresponding to the order in which they were made. This series comprises projectiles of all calibers made for the experiments.

SECTION I. RIFLE PROJECTILES.*

I. EXPERIMENTAL PROJECTILE No. 1.

(Plate VI.)

This is a cast-iron projectile and was finished when received. It was one of a lot of similar projectiles prepared under the direction of the Ordnance Board for like experiments.

* These projectiles were used with 3-inch M. L. rifled mortar.

It is cylindrical with sphero-segmental head. This shot is cast with a core, which leaves a hole through the shot from end to end. This hole is cylindrical for 2''.5 from the base; at which distance there is an annular shoulder ''.25 wide whose outer circle forms the smaller base of the frustum of a cone in which the hole is continued to the head of the shot.

The cylindrical part of this axial cavity is 2''.5 long and ''.6 in diameter; the conical (a frustum) part is 10''.75 long, with diameters of 1''.1 and 1''.3 at the smaller and larger ends, respectively. The base of this frustum is at the head of the shot. A straight groove, ''.6 wide and ''.5 deep runs the whole length of the shot and is parallel to the axis. The bottom of this groove is circular.

A radial slot 1'' deep and ''.6 wide, connects the longitudinal groove with the axial cavity.

The rifled motion is given by two rings of copper or brass studs, three in each ring. The distance between the two rings of studs is 6''.25, and the rear ring is situated 3''.15 from the base of the shot. The studs are radial, and are screwed into the shot.

The bearing edges of the studs are filed parallel to the line joining their centers. Within the axial cavity are contained a rubber plug and a lead washer through both of which the cord or line to be projected passes. The opening at the head of the shot is closed by a sheet-iron cap. This cap consists of a cylindrical body, on one end of which is brazed a circular head. The head, from its greater diameter, projects as a flange, which latter is curved downwards so as to embrace the point of the shot. The body has a hole pierced in one side to receive the screw which holds the cap in place when the shot is fired from the piece. This screw passes through the wall of the shot near the front end of the longitudinal groove, and its head is countersunk in the metal at the bottom of this groove.

1. Weights, dimensions, &c.

Projectile.

Total length	13.25 inches.
Diameter of body	2.94 inches.
Diameter of body over studs	3.12 inches.
Radius of head	1.47 inches.
Distance of center of gravity from base	6.30 inches.
Distance of first row of studs from base	3.15 inches.
Distance between first and second row of studs	6.25 inches.
Number of studs	6
Number of studs in each row	3
Height of studs	0.09 inch.
Width of studs	0.69 inch.
Front stud to right of rear stud (both for same groove)	0.5 inch.
Angle due to one turn in 10 feet	4° 30'
Weight, about	18 pounds.

2. Cap. (sheet-iron.)

Body.—Diameter	1.28 inches.
Length	1.2 inches.
Head.—Diameter	1.7 inches.

3. Washer. (lead.)

Diameter	1. inch.
Thickness	0.25 inch.
Diameter of hole	0.5 inch.

4. Rubber plugs.

Diameter.—Greatest	1.2 inches.
Least	1.07 inches.
Length	from 2 inches to 6 inches.
Diameter of longitudinal hole	0.5 inch.

5. Marks.

Only two of these shot were made and finished. They are marked on one of the rear studs C. 1 and C. 2, respectively.

II. EXPERIMENTAL PROJECTILE No. 2.

(Plate VII.)

This projectile is of the same general form as the preceding one. It differs only in the weight, and in the details of its dimensions and construction. The metal is cast iron except the studs, which are of brass. The following table and the drawings are sufficiently explanatory.

1. Dimensions, weight, &c.

Total length	10.3 inches.
Diameter of body	2.94 inches.
Diameter of body over studs	3.14 inches.
Radius of head	1.47 inches.
Distance of center of gravity from base	5. inches.
Distance of first row of studs from base	2.50 inches.
Distance between first and second row of studs	5. inches.
Number of studs	6
Number of studs in each row	3
Height of studs	0.10 inch.
Width of studs	0.69 inch.
Front stud to right of rear stud (both for same groove)	0.40 inch.
Angle due to one turn in 10 feet	4° 30.′
Longitudinal groove for short line. Length	Length of shot.
Width*	0.40 inch.
Depth*	0.37 inch.
Axial cavity.—Cylindrical portion, diameter of	0.60 inch.
Counterbore, front end, diameter of	1. inch.
Counterbore, front end, length of	2. inches.
Weight	16 pounds.

2. Cap. (sheet-iron.)

Body.—External diameter	1. inch.
Length	1.1 inches.
Head, diameter of	1.3 inches.

3. Washer. (brass.)

Diameter	1. inch.
Thickness	0.15 inch.
Diameter of hole	0.3 inch.

4. Marks.

Two shot of this pattern and size were made. They are marked on the rear studs as follows, viz: one, C. L. 3; the other, C. L. 4.

* The radial slot in the base has the same width and depth,

SECTION II. SMOOTH-BORE PROJECTILES.

I. 3-INCH SMOOTH-BORE PROJECTILES.

1. EXPERIMENTAL PROJECTILE No. 3.*

(Plate VIII.)

This is an elongated, solid, cast-iron smooth-bore projectile. In form, it is cylindro-ogival with a frustum of a cone for its base. The radius of the ogival head is equal to the diameter of the shot.

The edges or angles about the base are slightly rounded.

A *shank*, or eye-bolt, of wrought iron is screwed into the base of the projectile to serve as a point of attachment for the shot-line.

1. *Dimensions.*

Total length	13.8 inches.
Length of ogival head	2.6 inches.
Radius of head	3. inches.
Length of cylindrical part	9.9 inches.
Diameter of cylindrical part	3. inches.
Length of frustum	1.3 inches.
Diameter of smaller base of frustum	1.7 inches.
Shank: Total length	2.7 inches.
Length of screw	1.5 inches.
Diameter of screw	0.5 inch.
Length from plane of base	1.2 inches.
Distance from base to center of eye-hole	0.7 inch.
Diameter of eye-hole	0.4 inch.
Width at eye	1. inch.
Thickness at eye	0.4 inch.
Diameter of neck	0.625 inch.
Weight, about	22 pounds.

2. *Marks.*

Two of these shot were made and marked as follows: first, C. 5; second, C. 6.

2. EXPERIMENTAL PROJECTILE No. 4.

(Plate IX.)

The form and dimensions of the body of this shot are identical with those of "experimental projectile No. 3," (which see). The only difference is in the shank. The details of this projectile are fully shown in the drawing.

1. *Dimensions of shank, &c.*

Total length of shank, including screw	11.5	inches.
Length of screw-thread	1.5	inches.
Diameter of screw	0.5	inch.
Length of shank	10.	inches.
Diameter of shank	0.625	inch.
Diameter of eye-hole	0.4	inch.
Width at eye-hole	1.	inch.
Thickness at eye-hole	0.4	inch.
Distance from plane of base to center of eye	9.5	inches.
Distance of center of gravity from plane of base	5.97	inches.
Weight about	22	pounds.

* This and the two succeeding projectiles were made for 3″ M. L. rifled mortar.

2. *Marks.*

One shot, marked C. 7.

3. EXPERIMENTAL PROJECTILE No. 5.

(Plate X.)

This shot also differs from No. 3 only in the length and details of the shank.

1. *Dimensions of shank, &c.*

Total length of shank, including screw	7.5	inches.
Length of screw-thread	1.5	inches.
Diameter of screw	0.5	inch.
Length of shank	6.	inches.
Diameter of shank	0.625	inch.
Diameter of eye-hole	0.4	inch.
Width at eye-hole	1.	inch.
Thickness at eye-hole	0.4	inch.
Distance from plane of base to center of eye	5.5	inches.
Distance of center of gravity from plane of base	6.2	inches.
Weight, about	22	pounds.

2. *Marks.*

Two shot made, marked, respectively, C. 8 and C. 9.

4. EXPERIMENTAL PROJECTILE No. 17.*

(Plate XI.)

This is a cast-iron projectile whose body has the same form and dimensions as "experimental projectile No. 3." The shank, however, is different, being longer, and having the portion which screws into the shot much larger. For convenience all the dimensions are here given.

1. *Dimensions.*

Total length	13.8	inches.
Length of ogival head	2.6	inches.
Radius of head	3.	inches.
Length of cylindrical part	9.9	inches.
Diameter of cylindrical part	3.	inches.
Length of frustum	1.3	inches.
Diameter of smaller base of frustum	1.7	inches.
Shank: Total length	6.5	inches.
Length of screw	1.5	inches.
Diameter of screw	1.	inch.
Length from plane of base	5.	inches.
Distance from base to center of eye-hole	4.5	inches.
Diameter of eye-hole	0.4	inch.
Width at eye	1.	inch.
Thickness at eye	0.4	inch.
Diameter of neck	0.625	inch.
Weight, about	23	pounds.

2. *Marks.*

Five of these shot were made, and marked serially from C. 10 to C. 14, both inclusive.

*This form used with gun "A" bored to a caliber of 3 inches.

II. 2-INCH SMOOTH-BORE PROJECTILES.

These projectiles were fabricated for use in connection with experimental bronze gun "A," which was first bored out to a caliber of 2 inches.

1. Experimental projectile No. 6.

(Plate XII.)

This 2-inch shot is made of solid wrought iron. It is cylindro-ogival in form. The base is the frustum of a cone. The radius of the head is equal to one diameter of the shot. It has a wrought-iron shank like the 3-inch smooth-bore projectiles, to which it is similar in all respects except in material.

1. *Dimensions.*

Total length	13.	inches.
Length of ogival head	1.73	inches.
Radius of head	2.	inches.
Length of cylindrical part	10.27	inches.
Diameter of cylindrical part	2.	inches.
Length of frustum	1.	inch.
Diameter of smaller base of frustum	1.	inch.
Shank: Total length	6.5	inches.
Length of screw	1.5	inches.
Diameter of screw	0.5	inch.
Length from plane of base	5.	inches.
Distance from base to center of eye-hole	4.5	inches.
Diameter of eye-hole	0.4	inch.
Width at eye	1.	inch.
Thickness at eye	0.4	inch.
Diameter of neck	0.625	inch.
Distance of center of gravity from base	6.22	inches.
Weight, about	10	pounds.

2. *Marks.*

One shot made, marked LL. 1.

2. Experimental projectile No. 7.

(Plate XIII.)

The body of this one is the same as the preceding, but the shank differs somewhat. All the dimensions of the body are identical with those of No. 6.

1. *Dimensions of shank, &c.*

Total length	3.5	inches.
Length of screw	1.5	inches.
Diameter of screw	0.5	inch.
Length from plane of base	2.	inches.
Distance from base to center of eye-hole	1.5	inches.
Diameter of eye-hole	0.4	inch.
Width at eye	1.	inch.
Thickness at eye	0.4	inch.
Diameter of neck	0.625	inch.
Distance of center of gravity from base	6.25	inches.
Weight, about	10.	pounds.

2. *Marks.*

Two shot, LL. 2, and LL. 3.

3. EXPERIMENTAL PROJECTILE No. 8.

(Plate XIV.)

This shot has the same exterior form and dimensions as No. 6. The body is made of cast iron. A cylindrical cavity, whose axis is coincident with that of the shot, is bored out and filled with lead. This cavity occupies about two-thirds of the length of the projectile, and is drilled from the head or front end. A plug of wrought-iron screws into the open end, closing the cavity and forming the point of the shot. The shank, or eye-bolt, is of wrought iron. The details of construction are given in the drawings.

1. *Dimensions.*

Total length	13.	inches.
Length of ogival head	1.73	inches.
Radius of head	2.	inches.
Length of cylindrical part	10.27	inches.
Diameter of cylindrical part	2.	inches.
Length of frustum	1.	inch.
Diameter of smaller base of frustum	1.	inch.
Point of projectile—Total length	1.53	inches.
Head (ogival): Length	0.53	inch.
Diameter of base	1.20	inches.
Body (cylindrical): Length	1.	inch.
Diameter	1.10	inches.
Axial cavity (cylindrical): Total length	9.	inches.
Length filled with lead	8.	inches.
Diameter	1.	inch.
Shank: Total length	6.5	inches.
Length of screw	1.5	inches.
Diameter of screw	0.5	inch.
Length from plane of base of shot	5.	inches.
Distance from base to center of eye-hole	4.5	inches.
Diameter of eye-hole	0.4	inch.
Width at eye	1.	inch.
Thickness at eye	0.4	inch.
Diameter of neck	0.625	inch.
Distance of center of gravity from base ("LL. 4")	6.25	inches.
Distance of center of gravity from base ("LL. 5")	6.38	inches.
Weight, about	10.	pounds.

2. *Marks.*

Two shot made, marked LL. 4 and LL. 5.

4. EXPERIMENTAL PROJECTILE No. 9.

(Plate XV.)

This is a cast-iron projectile and is cast solid. The exterior is cylindro-ogival with a part of the point removed. A groove is planed along one side of the shot, parallel to the axis, for the accommodation of the shot-line. A transverse slot is cut in the rear end of the projectile to connect the axial cavity with the longitudinal groove.

The axial cavity is bored out and has the front end counterbored for the reception of the brass washer and the knot on the end of the line.

The cavity is closed in front by a cap held in position by a side screw.

1. *Weights, dimensions, &c.*

Total length	13.	inches.
Diameter of body	1.995	inches.
Radius of head	1.995	inches.
Distance of center of gravity from base	6.25	inches.
Longitudinal groove for shot-line: Length	Length of shot.	
Width	0.40	inch.
Depth	0.35	inch.
Groove in base for shot-line: Width	0.40	inch.
Depth	0.35	inch.
Axial cavity, cylindrical portion: Diameter	0.60	inch.
Counterbore, front end: Diameter	1.	inch.
Length	1.50	inches.
Weight	8.75	pounds.

2. *Cap.—(Sheet-iron.)*

Body: External diameter	1.	inch.
Length	1.1	inches.
Head: Diameter of	1.3	inches.

3. *Washer.—(Brass.)*

Diameter	1.0	inch.
Thickness	0.15	inch.
Diameter of hole	0.30	inch.

4. *Marks.*

Two shot were made, marked respectively LL. 6 and LL. 7.

5. EXPERIMENTAL PROJECTILE No. 13.*

(Plate XVI.)

The exterior dimensions of this shot are the same as those of No. 8. The shank in this instance extends axially through the entire length of the projectile. The front end of the shank is so shaped as to form the point of the projectile. The entire body of the projectile is of lead. The body is kept from turning on the shank by flattening the latter and raising some barbs on the angles with a cold-chisel.

1. *Dimensions.*

Point of projectile: Length of head	0.8	inch.
Diameter of base	1.55	inches.
Shank: Total length	18.	inches.
Length from base	5.	inches.
Distance from base to center of eye-hole	4.5	inches.
For other dimensions see "experimental projectile No. 8," and plate above cited.		
Weight	14.25	pounds.

2. *Marks.*

One shot, marked LL. O.

6. EXPERIMENTAL PROJECTILE No. 14.*

(Plate XVII.)

This is similar to projectile No. 8, from which it differs by having a heavier shank, and by having the axial cavity for the lead bored from

* Made for gun B.

the base of the shot. This leaves the head of the shot solid and diminishes the labor of manufacture. The dimensions wherein this projectile differs from No. 8 are given below. (See "Ex. proj. No. 8.")

1. *Dimensions.*

Diameter of small base of frustum	1.375	inches.
Axial cavity: Total length	11.5	inches.
Length filled with lead	10.	inches.
Diameter	1.	inch.
Shank: Diameter (exterior) of screw-thread	1.1	inches.
Diameter of neck	0.5625	inch.
Weight, about	11.	pounds.

2. *Marks.*

One shot made, marked LL. 8.

7. Experimental projectile No. 15.*

(Plate XVIII.)

This projectile is cylindro-ogival in form, with a frustum of a cone for its base. The body is of cast iron. An axial cavity is bored from the base nearly the whole length of the shot. Into this cavity melted lead is poured and allowed to cool, after which the shank is screwed in. The lead increases the weight of the shot without increasing its volume.

1. *Dimensions.*

Total length	15.	inches.
Length of ogival head	1.73	inches.
Radius of head	2.	inches.
Length of cylindrical part	12.27	inches.
Diameter of cylindrical part	2.	inches.
Length of frustum	1.	inch.
Diameter of smaller base of frustum	1.375	inches.
Axial cavity: Total length	13.5	inches.
Length filled with lead	12.	inches.
Diameter	1.	inch.
Shank: Total length	6.5	inches.
Length of screw-thread	1.5	inches.
Diameter (exterior) of screw-thread	1.1	inches.
Length from plane of base	5.	inches.
Distance from base to center of eye-hole	4.5	inches.
Diameter of eye-hole	0.4	inch.
Width at eye	1.	inch.
Thickness at eye	0.4	inch.
Diameter of neck	0.5625	inch.
Distance of center of gravity from base	7.	inches.
Weight, a little over	13.	pounds.

2. *Marks.*

Six of these projectiles were made and marked, consecutively, from LL. 9 to LL. 14, both numbers inclusive.

III. 2.5-INCH SMOOTH-BORE PROJECTILES.

These projectiles were fabricated for use with experimental bronze gun A, after it was bored out to a caliber of 2.5 inches.

* Made for gun B.

1. EXPERIMENTAL PROJECTILE No. 10.

(Plate XIX.)

This is a 2.5-inch projectile made of solid cast iron. The form is cylindro-ogival. A frustum of a cone forms the base.

The radius of the ogival head is equal to one diameter of the shot. A wrought-iron shank is screwed into the base, having an eye at its posterior extremity for attaching the line. For details of construction, see plate.

1. *Dimensions.*

Total length	13.3	inches.
Length of ogival head	2.17	inches.
Radius of head	2.5	inches.
Length of cylindrical part	10.03	inches.
Diameter of cylindrical part	2.5	inches.
Length of frustum	1.1	inches.
Diameter of smaller base of frustum	1.35	inches.
Shank: Total length	6.5	inches.
Length of screw	1.5	inches.
Diameter of screw	0.5	inch.
Length from plane of base	5.	inches.
Distance from base to center of eye-hole	4.5	inches.
Diameter of eye-hole	0.4	inch.
Width at eye	1.	inch.
Thickness at eye	0.4	inch.
Diameter of neck	0.5625	inch.
Distance of center of gravity from base	6.3	inches.
Weight, about	15	pounds.

2. *Marks.*

Two shot made, marked L. 1 and L. 2.

2. EXPERIMENTAL PROJECTILE No. 11.

(Plate XX.)

This is, also, a 2.5-inch projectile, made of solid cast iron. The body of this shot has the same form as that of No. 10, and differs only in the length and weight.

The ogival head is identical with that of No. 10. The wrought-iron shank, or eye-bolt, differs slightly from the one attached to the preceding shot, in that the screw-thread is shorter and the neck extends into the base of the projectile for 0''.4 without diminution of diameter. The hole in the base is counterbored to accommodate the increased size. The details are given in the following table of dimensions and upon the drawing of the projectile.

1. *Dimensions*

Total length	14.7	inches.
Length of ogival head	2.17	inches.
Radius of head	2.5	inches.
Length of cylindrical part	11.43	inches.
Diameter of cylindrical part	2.5	inches.
Length of frustum	1.1	inches.
Diameter of smaller base of frustum	1.35	inches.
Total length of hole for shank	1.5	inches.
Length of female screw	1.1	inches.
Length of counterbore	0.4	inch.
Diameter of female screw-hole	0.5	inch.
Diameter of counterbore	0.5625	inch.

Shank: Total length	6.5	inches.
Length of screw	1.1	inches.
Diameter of screw	0.5	inch.
Length of neck inserted in base of shot	0.4	inch.
Length from plane of base	5.	inches.
Distance from base to center of eye-hole	4.5	inches.
Diameter of eye-hole	0.4	inch.
Width at eye	1.	inch.
Thickness at eye	0.4	inch.
Diameter of neck	0.5625	inch.
Distance of center of gravity from base	7.	inches.
Weight, about	17	pounds.

2. *Marks.*

One shot made, marked L. 3.

3. Experimental projectile No. 12.

(Plate XXI.)

The length and weight of this projectile are greater than in the preceding one. In form and material it is the same. The shanks are also similar in every respect. The quantities given in the following table are the only ones in which this shot differs from projectile No. 11. (See plate.)

1. *Dimensions, &c.*

Total length	15.7	inches.
Length of cylindrical part	12.43	inches.
Distance of center of gravity from base	7.45	inches.
Weight, about	18	pounds.

2. *Marks.*

One shot made, marked L. 4.

4. Experimental projectile No. 16.*

(Plate XXII.)

This cast-iron shot is similar to No. 12, but it has a stronger shank. The details of form are fully shown in the plate.

1. *Dimensions.*

Total length	15.7	inches.
Length of ogival head	2.17	inches.
Radius of head	2.5	inches.
Length of cylindrical part	12.43	inches.
Diameter of cylindrical part	2.5	inches.
Length of frustum	1.1	inches.
Diameter of smaller base of frustum	1.35	inches.
Shank: Total length	6.5	inches.
Length of screw	1.5	inches.
Diameter of screw	1.	inch.
Length from plane of base	5.	inches.
Distance from base to center of eye-hole	4.5	inches.
Diameter of eye-hole	0.4	inch.
Width at eye	1.	inches.
Thickness at eye	0.4	inch.
Diameter of neck	0.625	inch.
Distance of center of gravity from plane of base	7.45	inches.
Weight, about	19	pounds

* Made for gun C.

2. *Marks.*

Nine shot made, numbered, serially, from L 5 to L 13, both inclusive.

Table of rifle projectiles.

Dimensions, &c.		Experimental projectiles.	
		No. 1.	No. 2.
Number of projectiles made		2	2
Caliber	inches	3	3
	centimeters	7. 62	7. 62
Marks, both inclusive		C. 1 and C. 2	C. L. 3 and C. L. 4
Total length	inches	13. 25	10. 3
	centimeters	33. 654	26. 162
Diameter of body	inches	2. 94	2. 94
	centimeters	7. 468	7. 468
Radius of head	inches	1. 47	1. 47
	centimeters	3. 734	3. 734
Distance of center of gravity from base	inches	6. 3	5.
	centimeters	16.	12. 70
Distance of first row of studs from base	inches	3. 15	2. 5
	centimeters	8.	6. 35
Distance between two rows of studs	inches	6. 25	5.
	centimeters	15. 875	12. 70
Number of studs		6.	6.
Number of studs in each row		3.	3.
Height of studs	inch	0. 09	0. 1
	centimeter	0. 229	0. 254
Width of studs	inch	0. 69	0. 69
	centimeters	1. 753	1. 753
Front stud to right of rear stud (both of same groove)	inch	0. 5	0. 4
	centimeters	1. 27	1. 016
Angle due to 1 turn in 10 feet (3.048 meters)		4° 30′	4° 30′
Longitudinal groove for shot-line:			
Width	inch	0. 6	0. 4
	centimeters	1. 524	1. 016
Depth	inch	0. 5	0. 37
	centimeters	1. 27	0. 94
Radial slot in base:			
Width	inch	0. 6	0. 4
	centimeters	1. 524	1. 016
Depth	inch	1.	0. 3
	centimeters	2. 54	0. 762
Axial cavity:			
Cylindrical part, diameter	inch	0. 6	0. 6
	centimeters	1. 524	1. 524
Counterbore front end—			
Diameter	inch	....	1.
	centimeters	....	2. 54
Length	inches	....	2.
	centimeters	....	5. 08
Weight, about	pounds	18	16
	kilograms	8. 16	7. 26

Weights of rifle projectiles.

Number.	Marks.	Weight.	
		Pounds.	Kilograms.
1	C. 1	18.	8. 159
2	C. 2	17. 75	8. 051
3	C. L. 3	16.	7. 258
4	C. L. 4	16. 25	7. 371

Table of 3-inch smooth-bore projectiles.

Dimensions, &c.		Experimental projectiles.			
		No. 3.	No. 4.	No. 5.	No. 17.
Number of projectiles made		2	1	2	5
Caliber	inches	3.	3.	3.	3.
	centimeters	7.62	7.62	7.62	7.62
Marks, both inclusive		C. 5 and C. 6	C. 7	C. 8, C. 9	C. 10 to C. 14
Total length	inches	13.8	13.8	13.8	13.8
	centimeters	35.051	35.051	35.051	35.051
Length of ogival head	inches	2.6	2.6	2.6	2.6
	centimeters	6.604	6.604	6.604	6.604
Radius of head	inches	3.	3.	3.	3.
	centimeters	7.62	7.62	7.62	7.62
Length of cylindrical part	inches	9.9	9.9	9.9	9.9
	centimeters	25.146	25.146	25.146	25.146
Diameter of cylindrical part	inches	3.	3.	3.	3.
	centimeters	7.62	7.62	7.62	7.62
Length of frustum	inches	1.3	1.3	1.3	1.3
	centimeters	3.302	3.302	3.302	3.302
Diameter of smaller base of frustum	inches	1.7	1.7	1.7	1.7
	centimeters	4.318	4.318	4.318	4.318
Shank:					
Total length	inches	2.7	11.5	7.5	6.5
	centimeters	6.858	29.209	19.05	16.51
Length of screw	inches	1.5	1.5	1.5	1.5
	centimeters	3.81	3.81	3.81	3.81
Diameter of screw	inch	0.5	0.5	0.5	1.
	centimeters	1.27	1.27	1.27	2.54
Length from plane of base	inches	1.2	10.	6.	5.
	centimeters	3.048	25.4	15.24	12.7
Distance from base to center of eye-hole	inches	0.7	9.5	5.5	4.5
	centimeters	1.778	24.13	13.97	11.43
Diameter of eye-hole	inch	0.4	0.4	0.4	0.4
	centimeters	1.016	1.016	1.016	1.016
Width at eye	inch	1.	1.	1.	1.
	centimeters	2.54	2.54	2.54	2.54
Thickness at eye	inch	0.4	0.4	0.4	0.4
	centimeters	1.016	1.016	1.016	1.016
Diameter of neck	inch	0.625	0.625	0.625	0.625
	centimeters	1.587	1.587	1.587	1.587
Distance of center of gravity from base	inches	....	5.97	6.2	....
	centimeters	....	15.164	15.748	....
Weight, about	pounds	22	22	22	23
	kilograms	9.979	9.979	9.979	10.433

Weights of 3-inch smooth-bore projectiles.

Number.	Marks.	Weight.	
		Pounds.	Kilograms.
1	C. 5	21.75	9.866
[illegible]	C. 6	21.75	9.866
[illegible]	C. 7	22.25	10.093
[illegible]	C. 8	21.875	9.922
[illegible]	C. 9	22.25	10.093
[illegible]	C. 10	22.59	10.248
[illegible]	C. 11	22.97	10.419
[illegible]	C. 12	23.062	10.46
[illegible]	C. 13	22.625	10.263
[illegible]	C. 14	22.906	10.39

Table of 2-inch smooth-bore projectiles.

Dimensions, &c.		Experimental projectile. No. 6.	No. 7.	No. 8.	No. 9.	No. 13.	No. 14.	No. 15.
					Cordes.			
Number of projectiles made		1.	2.	2.	2.	1.	1.	6.
Caliber	inches	2.	2.	2.	2.	2.	2.	2.
	centimeters	5.08	5.08	5.08	5.08	5.08	5.08	5.08
Marks, both inclusive		LL. 1	LL. 2 and LL. 3	LL. 4 and LL. 5	LL. 6 and LL. 7	LL. 0	LL. 8	LL. 9 to LL. 14
Total length	inches	13.	13.	13.	13.	13.	13.	15.
	centimeters	33.019	33.019	33.019	33.019	33.019	33.019	38.099
Length of ogival head	inches	1.73	1.73	1.73	....	1.73	1.73	1.73
	centimeters	4.394	4.394	4.394	....	4.394	4.394	4.394
Radius of head	inches	2.	2.	2.	1.995	2.	2.	2.
	centimeters	5.08	5.08	5.08	5.067	5.08	5.08	5.08
Length of cylindrical part	inches	10.27	10.27	10.27	....	10.27	10.27	12.27
	centimeters	26.086	26.086	26.086	....	26.086	26.086	26.086
Diameter of cylindrical part	inches	2.	2.	2.	1.995	2.	2.	2.
	centimeters	5.08	5.08	5.08	5.067	5.08	5.08	5.08
Length of frustum	inches	1.	1.	1.	....	1.	1.	1.
	centimeters	2.54	2.54	2.54	....	2.54	2.54	2.54
Diameter of smaller base of frustum.	inches	1.	1.	1.	....	1.	1.375	1.375
	centimeters	2.54	2.54	2.54	....	2.54	3.493	3.493
Shank:								
Total length	inches	6.5	3.5	6.5	....	18.	6.5	6.5
	centimeters	16.51	8.89	16.51	....	45.719	16.51	16.51
Length of screw	inches	1.5	1.5	1.5	....	....	1.5	1.5
	centimeters	3.81	3.81	3.81	....	....	3.81	3.81
Diameter of screw	inches	0.5	0.5	0.5	....	....	1.1	1.1
	centimeters	1.27	1.27	1.27	....	....	2.794	2.794
Length from plane of base.	inches	5.	2.	5.	....	5.	5.	5.
	centimeters	12.7	5.08	12.7	....	12.7	12.7	12.7
Distance from base to center of eye-hole.	inches	4.5	1.5	4.5	....	4.5	4.5	4.5
	centimeters	11.43	3.81	11.43	....	11.43	11.43	11.43
Diameter of eye-hole	inch	0.4	0.4	0.4	....	0.4	0.4	0.4
	centimeters	1.016	1.016	1.016	....	1.016	1.016	1.016
Width at eye	inches	1.	1.	1.	....	1.	1.	1.
	centimeters	2.54	2.54	2.54	....	2.54	2.54	2.54
Thickness at eye	inch	0.4	0.4	0.4	....	0.4	0.4	0.4
	centimeters	1.016	1.016	1.016	....	1.016	1.016	1.016
Diameter of neck	inch	0.625	0.625	0.625	....	0.625	0.5625	0.5625
	centimeters	1.587	1.587	1.587	....	1.587	1.429	1.429
Distance of center of gravity from base.	inches	6.22	6.25	6.25 6.38	6.25	6.25	....	.
	centimeters	15.799	15.875	15.875 16.205	15.875	15.875	....	17.78
Weight, about	pounds	10.	10.	10.	8.75	14.25	11.	13.
	kilograms	4.536	4.536	4.536	3.963	6.464	4.99	5.897

Weights of 2-inch smooth-bore projectiles.

Number.	Marks.	Weight. Pounds.	Weight. Kilograms.	Remarks.
1	LL. 1	10.406	4.72	Wrought iron.
2	LL. 2	10.437	4.734	Do.
3	LL. 3	10.375	4.706	Do.
4	LL. 4	10.406	4.72	Axial cavity.
5	LL. 5	10.562	4.799	Do.
6	LL. 6	8.75	3.963	Modified Cordes shot.
7	LL. 7	8.75	3.963	Do.
8	LL. 0	14.25	6.464	Made of lead.
9	LL. 8	11.156	5.06	Axial cavity.
10	LL. 9	13.156	5.967	Axial cavity, 13″.5 long.
11	LL. 10	13.156	5.967	Do.
12	LL. 11	13.156	5.967	Do.
13	LL. 12	13.219	5.996	Do.
14	LL. 13	13.281	6.024	Do.
15	LL. 14	13.25	6.01	Do.

Table of 2.5-inch smooth-bore projectiles.

Dimensions, &c.		Experimental projectile— No. 10.	No. 11.	No. 12.	No. 16.
Number of projectiles made		2.	1.	1.	9.
Caliber	inches	2.5	2.5	2.5	2.5
	centimeters	6.35	6.35	6.35	6.35
Marks, both inclusive		L.1 & L.2	L. 3	L. 4	L.5 to L.13
Total length	inches	13.3	14.7	15.7	15.7
	centimeters	33.781	37.337	39.877	39.877
Length of ogival head	inches	2.17	2.17	2.17	2.17
	centimeters	5.512	5.512	5.512	5.512
Radius of head	inches	2.5	2.5	2.5	2.5
	centimeters	6.35	6.35	6.35	6.35
Length of cylindrical part	inches	10.03	11.43	12.43	12.43
	centimeters	25.476	29.031	31.571	31.571
Diameter of cylindrical part	inches	2.5	2.5	2.5	2.5
	centimeters	6.35	6.35	6.35	6.35
Length of frustum	inches	1.1	1.1	1.1	1.1
	centimeters	2.794	2.794	2.794	2.794
Diameter of smaller base of frustum	inches	1.35	1.35	1.35	1.35
	centimeters	3.429	3.429	3.429	3.429
Shank:					
Total length	inches	6.5	6.5	6.5	6.5
	centimeters	16.51	16.51	16.51	16.51
Length of screw	inches	1.5	1.1	1.1	1.5
	centimeters	3.81	2.794	2.794	3.81
Diameter of screw	inch	0.5	0.5	0.5	1.
	centimeters	1.27	1.27	1.27	2.54
Length from plane of base	inches	5.	5.	5.	5.
	centimeters	12.70	12.70	12.7	12.7
Distance from base to center of eye-hole	inches	4.5	4.5	4.5	4.5
	centimeters	11.43	11.43	11.43	11.43
Diameter of eye-hole	inch	0.4	0.4	0.4	0.4
	centimeters	1.016	1.016	1.016	1.016
Width at eye	inch	1.	1.	1.	1.
	centimeters	2.54	2.54	2.54	2.54
Thickness at eye	inch	0.4	0.4	0.4	0.4
	centimeters	1.016	1.016	1.016	1.016
Diameter of neck	inch	0.5625	0.5625	0.5625	0.625
	centimeters	1.429	1.429	1.429	1.587
Distance of center of gravity from base	inches	6.3	7.	7.45	7.45
	centimeters	16.	17.78	18.923	18.923
Weight, about	pounds	15.	17.	18.	19.
	kilograms	6.804	7.711	8.159	8.618

Weights of 2.5 inch smooth-bore projectiles.

No.	Marks.	Weight. Pounds.	Kilos.	Remarks. Pounds. Kilos.	
1	L. 1	15.406	6.998	15.5 =7.031	Weights after being fitted with the shank used in experimental projectile No. 16. The new shanks were put in before sending them to Sandy Hook.
2	L. 2	15.406	6.998	15.562=7.059	
3	L. 3	17.109	7.761	17.343=7.867	
4	L. 4	18.437	8.357	18.531=8.400	
5	L. 5	18.75	8.499		
6	L. 6	18.75	8.499		
7	L. 7	18.75	8.499		
8	L. 8	18.75	8.499		
9	L. 9	18.781	8.513		
10	L. 10	18.75	8.499		
11	L. 11	18.75	8.499		
12	L. 12	18.75	8.499		
13	L. 13	18.75	8.499		

CHAPTER III.

GUN-CARRIAGES.

SECTION I.—CARRIAGES FOR 3-INCH M. L. RIFLED MORTAR.

I. CARRIAGE No. 1.

(Plate XXIII.)

The 3-inch M. L. rifled mortar was mounted on this carriage when received. The carriage had been used in making some preliminary experiments before being sent to the National Armory.

It consists of two cheeks and three transoms, made of oak; and of two trunnion plates, two cap-squares, twelve assembling bolts, twelve washers and twelve nuts, made of wrought iron.

The front and rear transoms project beyond the cheeks to form handles for convenience of transportation.

The middle transom is placed vertically between the cheeks, and is almost directly beneath the trunnions.

The ends of this transom are let into the cheeks. Two assembling bolts passing through the cheeks, and longitudinally through this (middle) transom, give rigidity to the cheeks.

The nuts and ends of the assembling bolts, which project below the cheeks, tend to check the recoil by sinking into the earth or sand.

The drawings furnish the dimensions and the details of construction.

Weight of carriage and quoin, 77 pounds.

II. CARRIAGE No. 2.

(Plate XXIV.)

This carriage was made at the National Armory. It differs in some of the details of its construction from carriage No. 1.

The cheeks are thicker, are not so long, and the number of parts is diminished. Iron handles are placed at the sides to be used in moving the gun and carriage from place to place.

The following are the component parts of this carriage, namely:

Two cheeks and front transom of wood (oak); two trunnion plates, two cap-squares, four handles, twelve assembling bolts, twelve nuts, one washer, and one rear transom of wrought iron.

A wooden quoin is used for giving elevations.

Weight of carriage and quoin, 68 pounds.

(See plate for dimensions, &c.)

SECTION II.—CARRIAGES FOR SMOOTH-BORE GUNS.

The carriages or beds for the smooth-bore bronze guns were all made at the National Armory, Springfield, Mass. The materials are oak and wrought iron.

I. CARRIAGE FOR BRONZE GUN A.

(Plate XXV.)

Nomenclature.

a. Wood.

2 checks, same size.
1 front transom.
1 quoin.

b. Wrought iron.

2 trunnion plates, same size.
2 cap-squares, same size.
2 hinge plates, same size.
2 hinge pins, same size (riveted).
2 cap-square keys, same size (rotating).
4 assembling bolts, long, same size.
4 assembling bolts, short, same size.
1 assembling bolt, transverse.
2 washers.
8 nuts.
1 rear transom.
4 handles.
2 cheek bands.

The two rear assembling bolts (long) screw into the hinge plates.

The cap-square keys rotate about the front assembling bolts (long) and lock the cap-squares when in position.

The cheek bands pass around the edges of the checks and are fastened to the latter by wood-screws.

These bands are made to fit closely.

The dimensions and details of the construction are given in the plate.

Weight of carriage and quoin, 63 pounds.

II. Carriage for bronze gun B.

(Plate XXVI.)

This carriage is similar in form to the preceding one, but is smaller and lighter. The rods that serve as handles for transportation are made long, in order that the load may be balanced by slipping the hands along the rods when two men carry the gun and carriage with the projectiles lying on the rear transom.

The nomenclature of this and the following carriage is the same as that for gun A.

Weight of carriage and quoin .... 35 pounds.
Weight of carriage alone .... 33.5 pounds.

(For details see plate.)

III. Carriage for bronze gun C.

(Plate XXVII.)

This carriage differs but slightly from that designed for gun A.

The trunnion beds and transoms in this carriage are placed farther forward, and the cheeks are cut away more in rear of the trunnions.

The drawings give all the details of construction and the dimensions.

Weight of carriage and quoin .... 54.25 pounds.
Weight of carriage alone (49.41 pounds) say .... 50 pounds.

Recapitulation of the weights of gun-carriages.

No.	Gun-carriage, with quoin.	Weight.		Remarks.
		Pounds.	Kilograms.	
1	No. 1 for 3" M. L. R. mortar..	77	34.93	
2	No. 2 for 3" M. L. R. mortar..	68	30.84	
3	For S. B. gun A	63	28.58	
4	For S. B. gun B............	35	15.88	Without quoin, 33.5 pounds (15.2 kilos.)
5	For S. B. gun C............	54.25	24.61	Without quoin, 50 pounds (22.68 kilos.)

CHAPTER IV.

POWDER, AND CARTRIDGE BAGS.

I. POWDER.

Two kinds of powder were used during the first series of experiments: Dupont's mortar powder and Hazard's United States Government musket powder.

The Dupont mortar powder used was a sample on hand when the experiments began.

The qualities of the Hazard musket powder used in this series of experiments are shown below in the report of Mr. R. T. Hare, in charge of the experimental apparatus at this armory. The arm and ammunition used, though not conforming to the actual conditions of service with life-saving guns and projectiles, afford relative tests of the values of different powders.

The pressures in all cases were taken with the Rodman pressure plug, with musket housing, using the National Armory circular cutter. There was no "internal-pressure gauge" suitable for use with the life-saving guns. The Le Boulengé chronograph, the Benton electro-ballistic machine, and the Benton thread velocimeter were employed in obtaining the initial velocities. These machines were used simultaneously for taking velocities.

Record of initial velocities.

[Station: National Armory, Springfield, Mass. Date: February 26, 1878. Kind of arm: Springfield rifle. Ammunition: Prepared. Weight of powder: 70 grains. Kind of powder: Hazard's United States Government Musket. Weight of ball: 405 grains. Object of experiment: To test velocity, pressure, and specific gravity of powder. Specific gravity: 1.80.]

Number of shot.	Le Boulengé.	Electro-ballistic.	Thread velocimeter.	Pressures per square inch.
	Feet.	*Feet.*	*Feet.*	*Pounds.*
1	1381.0	1393.2	1369.2	....
2	1330.8	1333.7	1334.9	....
3	1344.6	1345.3	1340.5	28,000
4	1361.2	1363.1	1357.5	27,000
5	1359.3	1363.1	1363.2	28,200
Mean	1355.3	1359.6	1353.0	27,733
Extreme variation .	50.2	59.5	34	....
Mean variation	7	8	6	....

Distance between targets for Le Boulengé: 98 feet. Distance between targets for electro-ballistic: 97 feet. Distance between targets for thread velocimeter: 100 feet. By whom taken: R. T. Hare.

Second series of experiments.

Four kinds of powder were procured from the Hazard Powder Company for this series of experiments, namely:

1. F. G., duck size ("Sea shooting duck").
2. U. S. Government musket.
3. Mortar.
4. Navy cannon.

The tests, as before, were made by Mr. Hare. They are given serially below.

The coarser grained powders were slightly compressed in putting up the metallic cartridges, which somewhat affected the resulting velocities and pressures.

No. 1.

Record of initial velocities.

[Station: National Armory, Springfield, Mass. Date: April 30, 1878. Kind of arm: Springfield rifle Ammunition: Prepared. Weight of powder: 70 grains. Kind of powder: Hazard sample, marked F. G., Duck Size.* Weight of ball: 405 grains. Object of experiment: To test velocity, pressure, and specific gravity of powder. Specific gravity: 1.79263.]

Number of shot.	Le Boulengé.	Electro-ballistic.	Thread velocimeter.	Pressures per square inch.
	Feet.	*Feet.*	*Feet.*	*Pounds.*
1	1325.9	1322.4	1323.7	31,000
2	1318.1	1316.7	1318.3	28,000
3	1335.7	1333.7	1334.9	25,700
4	1335.7	1339.4	1334.9	....
5	1335.7	1339.4	1329.3	....
Mean	1330.2	1330.3	1328.2	28,233
Extreme variation .	17.6	22.7	16.6	....
Mean variation	3.2	4.3	2.8	....

* Sometimes called "Sea Shooting Duck."

Distance between targets for Le Boulengé: 98 feet. Distance between targets for electro-ballistic: 97 feet. Distance between targets for thread velocimeter: 100 feet. By whom taken: R. T. Hare.

No. 2.

Record of initial velocities.

[Station: National Armory, Springfield, Mass. Date: April 30, 1878. Kind of arm: Springfield rifle Ammunition: Prepared. Weight of powder: 70 grains. Kind of powder: Hazard's sample, marked Musket Powder. Weight of ball: 405 grains. Object of experiment: To test velocity, pressure, and specific gravity of powder. Specific gravity: 1.81132.]

Number of shot.	Le Boulengé.	Electro-ballistic.	Thread velocimeter.	Pressures per square inch.
	Feet.	*Feet.*	*Feet.*	*Pounds.*
1	1354.4	1351.2	1375.0	33,900
2	1353.4	1351.2	1346.1	33,900
3	1367.1	1375.1	1375.0	33,900
4	1356.3	1363.1	1363.3	....
5	1357.3	1357.1	1351.7	....
Mean	1357.7	1359.5	1362.2	33,900
Extreme variation .	13.7	23.9	28.9	....
Mean variation	3	3.8	5.3	....

Distance between targets for Le Boulengé: 98 feet. Distance between targets for electro-ballistic 97 feet. Distance between targets for thread velocimeter: 100 feet. By whom taken: R. T. Hare.

No. 3.

Record of initial velocities.

[Station: National Armory, Springfield, Mass. Date: April 30, 1878. Kind of arm: Springfield rifle. Ammunition: Prepared. Weight of powder: 70 grains. Kind of powder: Hazard's sample, marked Mortar Powder. Weight of ball: 405 grains. Object of experiment: To test velocity, pressure, and specific gravity of powder. Specific gravity: 1.91202.]

Number of shot.	Le Boulengé.	Electro-ballistic.	Thread velocimeter.	Pressures per square inch.
	Feet.	*Feet.*	*Feet.*	*Pounds.*
1	1300.5	1300.3	1296.9	24,500
2	1307.0	1311.1	1313.0	25,000
3	1289.7	1294.8	1286.5	25,000
4	1313.2	1322.4	1307.6	....
5	1297.5	1300.3	1307.6	....
Mean	1301.5	1305.7	1302.3	25,000
Extreme variation .	23.5	27.6	26.5	....
Mean variation	3.4	4.5	4.2	....

Distance between targets for Le Boulengé: 98 feet. Distance between targets for electro-ballistic: 97 feet. Distance between targets for thread velocimeter: 100 feet. By whom taken: R. T. Hare.

No. 4.

Record of initial velocities.

[Station: National Armory, Springfield, Mass. Date: April 30, 1878. Kind of arm: Springfield rifle. Ammunition: Prepared. Weight of powder: 70 grains. Kind of powder: Hazard's sample, marked Navy Cannon. Weight of ball: 405 grains. Object of experiment: To test velocity, pressure, and specific gravity of powder. Specific gravity: 1.77061.]

Number of shot.	Le Boulengé.	Electro-ballistic.	Thread velocimeter.	Pressures per square inch.
	Feet.	*Feet.*	*Feet.*	*Pounds.*
1	1359.3	1357.1	1351.7	28,500
2	1328.9	1333.7	1334.9	29,500
3	1350.4	1363.1	1340.5	27,500
4	1329.9	1339.4	1323.7	....
5	1350.5	1322.4	1318.3	....
Mean	1343.8	1343.1	1333.8	28,500
Extreme variation .	30.4	40.7	33.4	....
Mean variation	5.7	6.8	5.1	....

Distance between targets for Le Boulengé: 98 feet. Distance between targets for electro-ballistic: 97 feet. Distance between targets for thread velocimeter: 100 feet. By whom taken: R. T. Hare.

II. Cartridge bags.

(Plate XXVIII, Figs. 1, 2.)

The cartridge bags are made of twilled serge, or some other woolen material.

The texture should be close enough to prevent the powder from sifting through.

Each bag is made of two pieces, identical in size and shape; one end of each half-bag is semicircular. The half-bags are cut out by means of sheet-iron or tin patterns. Marks for the seams are traced out by the cutter.

The seams are half an inch from the edge. After sewing, the edges are turned down on the same side of the seam and basted, to keep the powder from escaping through the seam.

Two sizes of bags are used.

Dimensions (of half cartridge bag).

For 3″ gun (Fig. 1.)

	Inches.	Centimeters.
Length	7.5	19.05
Width	4.5	11.43

For 2″ and 2″.5 guns (Fig. 2.)

	Inches.	Centimeters.
Length	7.0	17.78
Width	3.8	9.65

Shorter cartridge bags may be used for practice with small charges.

CHAPTER V.

SABOTS, FRICTION PRIMERS, AND IMPLEMENTS.

I. SABOTS.

(Plate XXIX.)

1. Three-inch sabots, wood. These were circular disks of dry pine. Two thicknesses were made, 0″.75 and 0″.5. (Figs. 1–4.)
2. Three-inch sabots, Cordes. This sabot is 3″ in diameter and 0″.55 thick. It has a disk of iron placed between two disks of sole leather, the whole held together by a copper rivet. (Figs. 5, 6.)
3. Two-inch sabots. Two kinds of sabots of this diameter were made; one was a plain wooden sabot and the other a Cordes sabot, similar to those above described. (See Figs. 7–10.)
4. Wads. In firing rifle projectiles and when using smooth-bore projectiles with the rifled mortar, wads of paper (newspapers) were used without any previous preparation.

II. FRICTION PRIMERS, ETC.

Three kinds of primers were used during the experiments, namely:

1. Service friction primer, short.
2. Service friction primer, long.
3. Electric primers.

III. PRIMING WIRE.

(Plate XXVIII, Fig. 3.)

This implement is made of brass or steel wire 0″.15 in diameter and is 7″.7 in length.* One end is pointed and the other is formed into a ring 2″.25 in diameter.

*Length 9″.7 in figure, but it has been found to be too long for convenience.

IV. SPONGE AND RAMMER.

(Plate III, Fig. 6.)

This is a staff of ash or elm 30″ long. The rammer head is cylindrical, 4″ long and 1″.75 in diameter. The end for the sponge is also cylindrical, and is 5″ in length with a diameter of 1″.5. The shaft between the heads is turned down to a diameter of 1″.25.

The sponge-head is made of coarse, well-twisted woolen yarn woven into a kind of webbed cloth, or of sheepskin with the wool on.

The thickness of the sponge-head may be so regulated that the same rammer may be used for the 2″ and 2″.5 guns.

V. POWDER MEASURES.

These are made of sheet-copper. Two sizes are made, one holding one ounce (avoirdupois) of powder (size of Navy cannon), and the other two ounces.

VI. LANYARD.

This is made of strong cod-line or of Nos. 3½, 4, or 4½ Silver Lake Company's braided linen line. A small hook of iron wire with an eye for the line is attached to one end of the lanyard, and to the other end a wooden toggle, 4″ long and 0″.75 in diameter. The lanyard should be 30 feet long. It is used for pulling off the friction primers.

VII. COMBINATION LEVEL.

(Plate XXVIII, Fig. 4.)

This is a foot-rule made of boxwood and bound with brass. It is a combination rule, level, and octant. A steel arm which closes like a knife blade is graduated into degrees from 0° to 45°. Half degrees may be estimated. It is used for obtaining elevations of guns and mortars when the chase or exterior near the muzzle in cylindrical. In the figure it is shown in position for an elevation of 30°.

VIII. GUNNER'S HAVERSACK.

(Plate XXX.)

This haversack is intended to be used for carrying cartridges, friction-primers, lanyard, priming wire, and the combination level. It is made of black bridle-leather, except the pocket for the friction-primers, which is made of black grain leather.

The back, bottom, front, and flap are cut in one piece. The ends are lined with leather to give them the requisite stiffness. On the inside of one end is a pocket for the combination level.

The inside flap has small pads sewed to the ends of the upper part to screen the inside of the haversack from the effects of a driving rain. Two loops are sewed or riveted to the back for the reception of the waist-belt. A tongue or "billet" fastens the outside flap to a brass button on the bottom. Sheaths for the priming-wire are sewed to each corner at the back of the haversack. A waist-belt and buckle completes the equipment. (For dimensions, &c., see plate.)

Nomenclature.

(Plate XXX.)

Fig. 1. Flap, back, bottom, and front, one piece.
Fig. 2. Inside flap.
Fig. 3, *a*. *b*. Pads on inside flap near top; should be same size.
Figs. 4, 5. Ends; lined.
Fig. 6. Pocket in front.
Fig. 7. Pocket for level.
Fig. 8. Lining for bottom.
Fig. 9. Sheath for priming-wire; one at each end.
Fig. 10. Tongue or billet.
Fig. 11. Loops for waist-belt; two.
Fig. 12. Waist-belt and buckle.
Fig. 13. View of haversack, complete.

NOTE.—If made for the service, the haversack will be made of russet leather.

CHAPTER VI.

SHOT-LINES.

These lines are intended to be used in connection with a gun or mortar and a projectile, to effect communication between the shore and stranded vessel, or, in exceptional cases, between vessels at sea.

They should be made of the very best materials.

The English method of faking has been adopted in laying up these lines for firing.

Rockets may be used instead of a gun and projectile for carrying the line.

The lines used in each series of experiments are given separately.

SECTION I.—LINES USED IN FIRST SERIES.

The cords or lines used in the first series of experiments were made expressly for the United States life-saving service.

The materials used were stated to be the best linen and Italian hemp thread. The cords are *braided* instead of being twisted, and each cord is made in one continuous piece. The first four lines were sent to the writer by Capt. J. H. Merryman, United States Revenue Marine, inspector of the life-saving service. These four lines are numbered serially for reference; the linen and hemp lines having a separate set of numbers. The manufacturer's numerical notation, when given, indicates the diameter of the line expressed in 32ds of an inch. Thus, when a line is designated as "No. 7," a line $\frac{7}{32}$ds of an inch in diameter is meant. The linen shot-lines had invariably a smooth finish; the hemp lines appeared to be less smooth upon the exterior.

1. *Linen line No.* 1.

Manufacturer unknown, probably Silver Lake Company, of Newtonville, Mass.

Maker's number not given, probably No. 7.

Theoretical diameter	0.21875	inch.
Measured diameter	0.22	inch.
Length	600	yards.
Weight of line	34	pounds.
Weight of faking-box, A 1	37	pounds.
Weight of faking-box and line	71	pounds.

2. *Linen line No.* 2.

Manufacturer unknown, probably Silver Lake Company.
Maker's number, No. 7.

Theoretical diameter	0. 21875	inch.
Measured diameter	0. 22	inch.
Length	600	yards.
Weight of line	33	pounds.
Weight of faking-box, A 2	36. 5	pounds.
Weight of faking-box and line	69. 5	pounds.

3. *Italian hemp line No.* 1.

Manufacturer unknown, probably Silver Lake Company.
Maker's number not given, probably No. 4½.

Theoretical diameter	0. 125	inch.
Measured diameter	0. 13	inch.
Length	700	yards.
Weight of line	16	pounds.
Weight of faking-box, B 1	24	pounds.
Weight of faking-box and line	40	pounds.

4. *Italian hemp line No.* 2.

Manufacturer unknown, probably Silver Lake Company.
Maker's number not given, probably No. 4½.

Theoretical diameter	0. 125	inch.
Measured diameter	0. 13	inch.
Length	700	yards.
Weight of line	13. 5	pounds.
Weight of faking-box, B 2	24	pounds.
Weight of faking-box and line	37. 5	pounds.

5. *Linen line No.* 3.

This small line was made especially for trial with a light gun to ascertain the maximum range that could be obtained without breaking the line, and also to learn if so small a line would stand the shock of discharge. It was made of bleached linen thread under the direction of Mr. H. W. Wellington, the agent and manager of the Silver Lake Company, of Newtonville, Mass. It is what rope-makers term *hard-laid*, that is, it is made very hard and compact in braiding and finishing. It was made in a single piece.

Dimensions, &c.

Maker's number		No. 3½
Theoretical diameter	0. 109375	inch.
Measured diameter	0. 1	inch.
Length	800	yards.
Weight of line	7. 625	pounds.
Weight of faking-box, B	24	pounds.
Weight of faking-box and line	31. 625	pounds.

6. *Time required for faking the different shot-lines.*

Date, 1877.		Shot-line.		Time of faking.	Faking-box, size.	Remarks.
Month.	Day.	Kind.	Length.			
			Yds.	*Mins.*		
October...	12	Linen, No. 1.	600	40	A	Line in coils taken up by winding around hand and elbow after firing.
	12	Hemp, No. 1.	700	31	B	Line in coils taken up by winding around hand and elbow after firing.
	17	Hemp, No. 1.	700	28	B	Line in box; not carried out by shot.
	17	Hemp, No. 2.	700	28	B	Line in box; not carried out by shot.
	25	Hemp, No. 2.	700	40	B	Line on reel; assistant absent ten minutes.
	25	Linen, No. 2.	600	21	A	Line on reel.
November	4	Hemp, No. 1.	700	28	B	Line in coils; wound up on arm.
	4	Hemp, No. 2.	700	27	B	Line in coils; wound up on arm.
	4	Linen, No. 1.	600	24	A	Line in coils; wound up on arm; piece broken off line.
	4	Linen, No. 2.	600	22	A	Line in coils; wound up on arm.
	22	Linen, No. 1.	600	20	A	Line in coils; wound up on arm; piece broken off line.
	22	Linen, No. 3.	800	40	B	Line in coil as received from maker; interrupted by snarls.
	27	Linen, No. 3.	750	28	B	Line in coils; wound on arm; fifty yards broken off.
	27	Hemp, No. 2.	700	17	B	Line on reel.
	27	Linen, No. 2.	600	22	A	Line on reel.

NOTE.—The writer did the faking in each instance. An assistant was required to press down the loops on the side of the box opposite to the faker, while a helper paid the line out of the coils or from the reel.—D. A. L.

SECTION II. LINES USED IN SECOND SERIES OF EXPERIMENTS.

1. *Experimental shot-lines.*

The braided shot-lines used in the second series of experiments were manufactured by the Silver Lake Company, of Newtonville, Mass.

The lines having the "ordinary finish" were procured by the Treasury Department, while those having the "water-proof finish" were furnished, free of expense to the government, by Mr. H. W. Wellington, of the firm of Wellington Bros., of Boston, Mass., who requested that they be tried at the same time with the other lines for the purpose of determining their relative merits.

The braiding of these lines is done by an ingenious machine, the invention of the late James Amiraux Bazin, of Canton, Norfolk County, Mass.

Referring to this process of making lines or ropes, the inventor states:

In the usual method of making ropes it is necessary to give the yarns a much harder twist than would be essential for binding the separate fibers together in order to compensate for what is taken out by the countertwist of the strand, thereby making it necessary, in laying these strands up into a rope, to give them a much harder twist than would otherwise be required, as it is the tendency of each strand to untwist that keeps them all firmly bound together; a hard-twisted rope necessarily requiring an equally hard twist in the strands, and thereby causing a constant strain upon all the fibers of which it is composed.

But where a soft and pliable rope is required, as the twist in the strands must be proportionally reduced, the strands will be liable to be thrown out of place and into kinks by careless usage.

To obviate this, ropes are sometimes made by braiding, which, though it prevents the strands from being thrown out of place, is still more objectionable, as the strands in this case run around spirally in contrary directions, and consequently a slight twisting of the rope either way will throw all the strain upon *one-half* the number of strands.

To overcome the above-mentioned difficulties is the object of my invention, which consists in combining the strands of any fibrous material by an interlocking twist, in

which the strands all take the same spiral form that they would have in a twisted rope of ordinary manufacture, and yet hold each other in place more effectually than can be done by braiding; this interlocking twist being formed by successively passing each strand around two others, so that each of the two so entwined shall, in its turn, entwine two others; and as the strands all maintain the same spiral form irrespective of the twist in each, there can be no unnecessary strain upon the fibers of which they are composed, while, under all circumstances, each strand will bear an equal amount of strain with all the others, and cannot possibly kink or become misplaced.

And my invention also consists in a new machine for forming the above-described interlocking twist, in which the spools that carry the strands are so actuated that two of the strands are held stationary while another is passing around them, thereby interlocking the strands as above described; and my invention furthermore consists in so arranging the mechanism as to permit of its being operated in either direction, as may be desired, according to the twist in the yarns of which the strands are composed.

The spool-carriers are always made to revolve in the same direction as the twist of the strands.

The inventor does not limit himself to any particular number of spools, provided only that the number shall be *a multiple of three.*

The number of "*travelers*" or spool-carriers employed in the machines for braiding the experimental lines for the United States Life-Saving Service were *nine* and *twelve*, depending upon the size of the lines.

2. *Materials.*

Linen and Italian hemp threads were used in the fabrication of the experimental lines.

The linen yarns were all furnished by the Smith & Dove Manufacturing Company, of Andover, Mass., and the Italian hemp yarns by the Boston Flax Mills.

In the process of braiding, a core of the same material is sometimes inserted.

The lines made on the twelve "*traveler*" machines are a little firmer, and the strands come to their places better with a core; but this is not indispensable, and, unless the yarn is harsh, the core is often omitted.

3. *Finishing.*

1. "Ordinary finish."

The lines are finished by being drawn rapidly twice through wheat-starch.

The extra starch is wiped from the line by passing it through a piece of India rubber. It is then passed through a closely-fitting steel die, two inches in length. After drying a few moments, the cord is passed twice through another steel die, slightly smaller than the first. The latter operation gives the cord a polish and smooths the exterior.

2. "Water-proof finish."

The "water-proofed" lines are passed slowly through a hot mixture of linseed-oil, bees-wax, and paraffine before receiving the usual finish.

The writer is indebted to Mr. James Tolman, of Boston, for the above details, as well as the following tabular statement in regard to the manufacture of braided lines:

4. *Materials, &c., used in the manufacture of shot-lines from Wellington Bros. & Co., agents for Silver Lake Company.*

Maker's number.*	Material.	Color.	Yarn.	Number of "travelers" in the braiding-machine.	Length.	Weight.
					Yds.	*Lbs.*
3½	Linen	Bleached	Andover, 3 cord, No. 16	9	700	7.
4	do	do	Andover, 5 cord, No. 16	9	700	12.5
4½	do	do	Andover, 5 cord, No. 10	9	700	13.
5	do	do	do	12	700	24.
6	do	Unbleached	Andover sail twine, 3 ply, 2 ends	12	600	31.5
7	do	do	Andover sail twine, 7 ply	12	600	33.
8	do	do	Andover sail twine, 3 ply, 3 ends	12	600	50.5
9	do	do	Andover sail twine, 3 ply, 4 ends	12	600	55.5
10	do	do	Andover sail twine, 3 ply, 5 ends	12	600	63.5
3½	Italian hemp	Natural	Wet spun, 6 cord	9	700	7.
4	do	do	Wet spun, 6 cord, 2 ply	9	700	13.
4½	do	do	Dry spun, 6 cord, 3 ply	9	700	15.5
5	do	do	Dry spun, 6 cord, 4 ply	12	700	26.
6	do	do	Dry spun, 6 cord, 5 ply	12	600	31.
7	do	do	Dry spun, 6 cord, 6 ply	12	600	38.
8	do	do	Dry spun, 6 cord, 7 ply	12	600	41.5
9	do	do	Dry spun, 6 cord, 8 ply	12	600	53.5
10	do	do	Dry spun, 6 cord, 10 ply	12	600	64.5
4	Dark linen	Unbleached	Andover, 3 ply, sail twine	9	700	14.5

*The maker's number indicates the diameter of the cord in thirty-seconds of an inch.

5. *Dimensions, weights, tests, &c.*

The following sets of tables give all the details in regard to these lines.

The two tables forming each set belong to the same group of lines. Lines Nos. 8, 9, and 10 of each group were not provided with faking-boxes, from motives of economy. The breaking weights and "stretch in six feet" are approximations only. The former was obtained by taking sections of each cord and carefully attaching them to two small grooved pulleys in such a way as to avoid cutting the cord at the knots. The length of cord between the knots was invariably six feet. One pulley was hung from a beam, and to a hook on the other was attached a large bucket. Lead weights were gradually placed in the bucket until the cord broke. The total load was carefully weighed in each instance.

Very small weights were used as the load neared the breaking weight or stress.

The *stretch* or increase of length of the cord was obtained by a vertical scale properly adjusted; an index or pointer attached to the side of the pulley on the lower end of the line assisted the observer in following the indications and taking the readings.

In other respects the tables are self-explanatory.

TABLE I.

A.

Experimental braided shot-lines of Italian hemp, made by Silver Lake Company, ordinary finish.

Number of lines.	Maker's number.	Material.	Length.		Diameter measured.		Weight.		Faking-box.		
			Yards.	Meters.	Inches.	Millimeters.	Pounds.	Kilograms.	Size.	Weight. Pounds.	Weight. Kilograms.
1	3½	Italian hemp	700	640. 068	0. 095	2. 413	7. 0	3. 175	D	19. 5	8. 845
1	4	......do	700	640. 068	. 125	3. 175	13. 0	5. 896	B	23. 5	10. 659
1	4½	......do	700	640. 068	. 145	3. 683	15. 5	7. 030	B	24. 0	10. 886
1	5	......do	700	640. 068	. 190	4. 826	26. 0	11. 793	C	33. 0	14. 968
1	6	Italian hemp, sash	600	548. 63	. 215	5. 461	31. 0	14. 061	A	42. 0	19. 051
1	7	......do	600	548. 63	. 235	5. 969	38. 0	17. 236	A	36. 5	16. 556
1	8	......do	600	548. 63	. 265	6. 731	42. 0	19. 051	......	......	......
1	9	......do	600	548. 63	. 285	7. 239	53. 0	24. 040	......	......	......
1	10	......do	600	548. 63	. 325	8. 255	64. 5	29. 257	......	......	......

B.

Tensile strength and elongation of braided shot-lines, made of Italian hemp, by Silver Lake Company, ordinary finish.

Number of lines.	Maker's number.	Material.	Breaking weight.		Stretch in six feet of line.	
			Pounds.	Kilograms.	Inches.	Millimeters.
1	3½	Italian hemp	70	31. 751	9. 0	228. 60
1	4	......do	90	40. 823	6. 0	152. 40
1	4½	......do	90	40. 823	7. 5	190. 50
1	5	......do	252	114. 306	11. 0	279. 39
1	6	Italian hemp, sash	300	136. 079	12. 0	304. 79
1	7	......do	350	158. 759	10. 5	266. 70
1	8	......do	467	211. 829	14. 0	355. 59
1	9	......do	530	240. 406	12. 0	304. 79
1	10	......do	673	305. 270	11. 5	292. 09

TABLE II.

A.

Experimental shot-lines, linen, braided, made by Silver Lake Company, ordinary finish.

Number of lines.	Maker's number.	Material.	Length.		Diameter measured.		Weight.		Faking-box.		
			Yards.	Meters.	Inches.	Millimeters.	Pounds.	Kilograms.	Size.	Weight. Pounds.	Weight. Kilograms.
1	3½	Bleached linen	700	640. 068	0. 092	2. 3368	7. 0	3. 175	D	18. 0	8. 164
1	4	......do	700	640. 068	. 127	3. 226	12. 5	5. 670	B	24. 0	10. 886
1	4½	......do	700	640. 068	. 133	3. 378	13. 0	5. 896	B	23. 5	10. 659
1	5	......do	700	640. 068	. 160	4. 064	24. 0	10. 886	C	33. 0	14. 968
1	6	Unbleached linen, sash	600	548. 63	. 210	5. 334	33. 0	14. 968	A	34. 0	15. 422
1	7	......do	600	548. 63	. 225	5. 715	33. 0	14. 968	A	35. 0	15. 875
1	8	......do	600	548. 63	. 275	6. 985	50. 5	22. 906	......	......	......
1	9	......do	600	548. 63	. 283	7. 188	55. 5	25. 174	......	......	......
1	10	......do	600	548. 63	. 322	8. 179	63. 5	28. 803	......	......	......

B.

Tensile strength and elongation of braided shot-lines, made of linen thread, by Silver Lake Company, ordinary finish.

Number of lines.	Maker's number.	Material.	Breaking weight.		Stretch in six feet of line.	
			Pounds.	Kilograms.	Inches.	Millimeters.
1	3½	Bleached linen	102.0	46.266	6.0	152.40
1	4	......do	160.0	72.575	9.0	228.60
1	4½	......do	143.5	65.091	9.0	228.60
1	5	......do	245.0	111.131	8.5	215.90
1	6	Unbleached linen, sash	323.0	146.511	13.0	330.19
1	7	......do	391.0	177.356	12.5	317.49
1	8	......do	542.0	245.849	14.0	355.59
1	9	......do	683.0	309.806	13.0	330.19
1	10	......do	795.0	360.609	13.0	330.19

TABLE III.

A.

Experimental braided shot-lines of Italian hemp, made by Silver Lake Company, water-proof finish.

Number of lines.	Maker's number.	Material.	Length.		Diameter, measured.		Weight.		Faking-box.		
										Weight.	
			Yards.	Meters.	Inches.	Millimeters.	Pounds.	Kilograms.	Size.	Pounds.	Kilograms.
1	3½	Italian hemp	700	640.068	0.100	2.540	8.0	3.628	D	18.0	8.164
1	4	......do	700	640.068	.120	3.048	14.0	6.350	B	23.0	10.432
1	4½	......do	700	640.068	.140	3.556	14.5	6.577	B	24.5	11.113
1	5	......do	700	640.068	.200	5.080	27.5	12.473	C	32.0	14.515
1	6	Italian hemp, sash	600	548.63	.210	5.334	27.0	12.247	A	36.0	16.329
1	7	......do	600	548.63	.225	5.715	37.5	17.009	A	35.5	16.102
1	8	......do	600	548.63	.274	6.985	42.0	19.051	......	......	......
1	9	......do	600	548.63	.295	7.493	53.0	24.040	......	......	......
1	10	......do	600	548.63	.320	8.128	55.5	25.174	......	......	......

B.

Tensile strength and elongation of braided shot-lines, made of Italian hemp, by Silver Lake Company, water-proof finish.

Number of lines.	Maker's number.	Material.	Breaking weight.		Stretch in six feet of line.	
			Pounds.	Kilograms.	Inches.	Millimeters.
1	3½	Italian hemp	60	27.215	5.0	127.00
1	4	......do	110	49.896	5.0	127.00
1	4½	......do	157	71.215	6.0	152.40
1	5	......do	232	105.688	6.0	152.40
1	6	Italian hemp, sash	258	117.028	7.0	177.80
1	7	......do	320	145.151	8.0	203.20
1	8	......do	434	196.861	8.5	215.90
1	9	......do	476	215.912	11.0	279.39
1	10	......do	600	272.158	10.0	254.00

TABLE IV.

A.

Experimental braided linen shot-lines, made by Silver Lake Company, water-proof finish.

Number of lines.	Maker's number.	Material.	Length.		Diameter, measured.		Weight.		Faking-box.		
			Yards.	Meters.	Inches.	Millimeters.	Pounds.	Kilograms.	Size.	Weight. Pounds.	Weight. Kilograms.
1	3½	Linen, bleached	700	640.068	0.100	2.540	8.0	3.628	D	18.5	8.391
1	4	......do	700	640.068	.122	3.094	14.5	6.577	B	24.	10.886
1	4½	......do	700	640.068	.139	3.530	15.5	7.030	B	24.	10.886
1	5	......do	700	640.068	.175	4.445	24.0	10.886	C	31.5	14.288
1	6	Unbleached linen, sash	600	548.63	.225	5.715	31.5	14.288	A	36.5	16.556
1	7	......do	600	548.63	.225	5.715	33.5	15.195	A	35.5	16.102
1	8	......do	600	548.63	.280	7.112	51.0	23.133	......	......	......
1	9	......do	600	548.63	.285	7.239	54.0	24.494	......	......	......
1	10	......do	600	548.63	.335	8.509	70.0	31.751	......	......	......

B.

Tensile strength and elongation of braided shot-lines, made of linen thread by Silver Lake Company, water-proof finish.

Number of lines.	Maker's number.	Material.	Breaking weight.		Stretch in six feet of line.	
			Pounds.	Kilograms.	Inches.	Millimeters.
1	3½	Linen, bleached	91	41.277	5.	127.00
1	4	......do	137	62.142	8.	203.20
1	4½	......do	145	65.771	7.5	190.50
1	5	......do	268	121.563	7.5	190.50
1	6	Unbleached linen, sash	337	152.862	12.	304.79
1	7	......do	410	185.974	12.	304.79
1	8	......do	480	217.726	11.	279.39
1	9	......do	624	273.044	13.	330.19
1	10	......do	769	348.816	13.	330.19

TABLE V.

A.

Experimental braided shot-lines, unbleached linen thread, made by Silver Lake Company.

Number of lines.	Maker's number.	Material.	Length.		Diameter, measured.		Weight.		Faking-box.		
			Yards.	Meters.	Inches.	Millimeters.	Pounds.	Kilograms.	Size.	Weight. Pounds.	Weight. Kilograms.
1	4	Unbleached linen	700	640.068	0.127	3.226	14.5	6.577	B	23.5	10.659
1	4	Unbleached linen, W. P.	700	640.068	0.125	3.175	16.5	7.484	B	25.0	11.340

NOTE.—These lines are invoiced as "Dark linen."

B.

Tensile strength and elongation of braided shot-lines, made of unbleached linen thread by the Silver Lake Company.

Number of lines.	Maker's number.	Material.	Breaking weight.		Stretch in six feet of line.		Remarks.
			Pounds.	Kilograms.	Inches.	Millimeters.	
1	4	Unbleached linen	172	78.018	7.	177.8	Ordinary finish.
1	4	Unbleached linen, W. P.	145	65.771	9.5	241.3	Water-proof finish.

III. Reel for shot-lines.

(Plate XXXV.)

It was found necessary during the experimental firing to have some method of taking up the lines rapidly, and, at the same time, one that would keep them from becoming entangled.

A light reel was designed for this purpose which answered all the requirements. This simple contrivance consists of a frame, reel, and crank of wood, and of two wire pins.

The frame is dovetailed together, and has four small D-rings attached to it by bits of leather. These rings engage with the snap-hooks of the carrying-braces. The reel is composed of an arbor, carrying cross-pieces at each end. The arbor is retained in the frame by the wire pins.

A strip of leather passes over the extremities of the cross-pieces at each end to keep the radial arms from catching in the line when winding it up.

Dimensions and details of construction may be seen in the drawings. Weight of reel complete, 8 pounds.

IV. Carrying-braces for reel.

(Plate XXXVI.)

These braces were made to carry the reel and frame.

They consist of a waist-belt and a set of light cross-belts or braces, with snap-hooks for attaching the reel-frame.

The operator walks along, winding up the line as he proceeds, thus preserving the line from injuries which would result from dragging it through the sand, over rocks and bushes. (See plate for details.) Weight, 1 pound.

CHAPTER VII.

FAKING-BOXES.

These boxes are designed for placing the shot-lines in position for firing. The lines are stowed away in the boxes in a peculiar manner, called "faking." The method is one adopted by the English for the stowage of their rocket-lines.

I. FAKING-BOX A (large).

(Plate XXXI.)

1. *Description.*

		Inches.	Centim'rs.
External dimensions	Length	36.0	=91.438
	Width	19.9	=50.545
	Depth	12.75	=32.384
Internal dimensions	Length	34.9	=88.644
	Width	18.8	=47.751
	Depth	12.2	=30.987

2. *Weight.*

	Lbs.	Kilos.
Average weight, empty	35	=15.875
Average weight, with "braided linen line, Silver Lake Co., No. 6," about	66.5	=30.163
Average weight, with "braided linen line No. 7"	68	=30.843

3. *Material.*

This box is made of well-seasoned white pine. The faking-pins are made of hickory, and the frame for these pins of ash.

4. *Nomenclature and dimensions.*

		Inches.	Centim'rs.
1 top	Length	36.0	=91.438
	Width	19.9	=50.545
	Thickness	.55	= 1.397
2 side pieces, same size	Length	36.0	=91.438
	Width	12.2	=30.987
	Thickness	.55	= 1.397
2 end pieces, same size	Length	19.9	=50.545
	Width	12.2	=30.987
	Thickness	.55	= 1.397
1 "false bottom"	Length	34.6	=87.882
	Width	18.6	=47.243
	Thickness	.55	= 1.397

Frame for faking-pins.

		Inches.	Centim'rs.
2 side pieces, same size	Length	38.0	=96.519
	Width	3.75	= 9.525
	Thickness	.9	= 2.286
2 end pieces, same size	Length	21.0	=53.339
	Width	4.2	=10.668
	Thickness	.9	= 2.286

Faking-pins.

			Inches.	Centim'rs.
48 pins, same size	Total length		12.4	=31.495
	Body	Length	11.5	=29.209
		Greatest diameter	1.0	= 2.540
		Least diameter	.35	= .889
	Screw	Length	.9	= 2.286
		Diameter	.7	= 1.778
2 cleats for rope handles, same size		Length	6.2	=15.748
		Width	2.0	= 5.080
		Thickness	1.4	= 3.556
2 handles, hemp rope		Length	18.0	=45.719
		Diameter	.5	= 1.270

2 hasps, metal, for fastening box to frame.

5. *Construction.*

The sides and ends are dovetailed together at the corners. The top is nailed to the ends and sides with one-and-a-half-inch and six-penny finishing nails. The cleats carrying the rope-handles are fastened to the box, one at each end, by four small screws.

The "false bottom" has a row of holes, 1″.2 (3.05 centimeters) in diameter, around the perimeter. Along the sides and ends the centers of these holes are situated 1″.3 (3.3 centimeters) from the edges. The distance between the centers of any two consecutive holes is 2″ (5.08 centimeters).

The sides and ends of the frame for the faking-pins are put together with mortises and tenons.

Along the sides, the centers of the screw-holes for the faking-pins are placed 2″.5 (6.35 centimeters) from the outer edges; the centers of these holes are 3″ (7.62 centimeters) from the outer edges along the ends of the frame.

The distance between the centers of any two consecutive screw-holes is 2″ (5.08 centimeters).

These holes are bored and tapped to form a coarse-threaded female screw.

There are seventeen holes on each side and seven at each end of both the bottom and the frame, making forty-eight holes in each.

The faking-pins are turned in a lathe from pieces of hickory of the proper length. The body is a frustum of a cone. The upper end is slightly rounded off. A coarse, cylindrical screw is cut upon the lower end.

A metallic hasp which passes over a button attached to the end of the box is fastened to each end of the frame, and serves to hold the frame and box together in transportation and handling.

In the boxes usually made for the United States Life-Saving Service, an iron staple takes the place of the hasp, and a staple and hook of the same material supplants the button; but they form a very insecure fastening. In handling the boxes the hooks are apt to become disengaged and let the frame and line fall, thus increasing the chances of entangling the latter.

The outside of the box is painted a deep blue, with narrow marginal stripes of red.

6. *Marks.*

The letters "U. S. L. S. S." are painted in *white* upon the top.

II. FAKING-BOX B (small).

(Plate XXXII.)

1. *Description.*

		Inches.	Centim'rs.
External dimensions	Length	24.0	= 60.959
	Width	16.0	= 40.639
	Depth	12.8	= 32.511
Internal dimensions	Length	22.8	= 57.911
	Width	14.8	= 37.591
	Depth	12.2	= 30.987

2. *Weight.*

	Lbs.	Kilos.
Average weight, empty	24	= 10.886
Average weight, with "linen line No. 4," about	36.5	= 16.556
Average weight, with "linen line No. 4½," about	37	= 16.782

3. *Materials.*

The box and "false bottom" are made of white pine; the faking-pins of hickory; the frame of ash; all well seasoned.

4. *Nomenclature and dimensions.*

		Inches.	Centim'rs.
1 top	Length	24.0	= 60.959
	Width	16.0	= 40.639
	Thickness	.6	= 1.524
2 side pieces, same size	Length	24.0	= 60.959
	Width	12.2	= 30.987
	Thickness	.6	= 1.524
2 end pieces, same size	Length	16.0	= 40.639
	Width	12.2	= 30.987
	Thickness	.6	= 1.524
1 "false bottom"	Length	22.6	= 57.403
	Width	14.6	= 37.083
	Thickness	.6	= 1.524

Frame for faking-pins.

2 side pieces, same size	Length	26.0	= 66.039
	Width	3.7	= 9.398
	Thickness	.9	= 2.286
2 end pieces, same size	Length	17.0	= 43.179
	Width	4.3	= 10.922
	Thickness	.9	= 2.286

Faking-pins.

32 pins, same size	Total length		12.4	= 31.495
	Body	Length	11.5	= 29.209
		Greatest diameter	1.0	= 2.540
		Least diameter	.35	= .889
	Screw	Length	.9	= 2.286
		Diameter	.7	= 1.778

		Inches.	Centim'rs.
2 cleats for rope handles, same size	Length	6.2	= 15.748
	Width	2.0	= 5.080
	Thickness	1.4	= 3.556
2 handles, hemp rope	Length	18.0	= 45.719
	Diameter	.5	= 1.270

2 hasps, metal, for fastening box to frame.

5. *Construction.*

The general construction of this box differs from the one given above in the following particulars only, viz:

1. In having 32 instead of 48 faking-pins.
2. In having 32 instead of 48 holes in bottom.
3. In having 32 instead of 48 screw holes in frame.

The distances of the holes, etc., from the outer edge of the bottom and of the frame, and from each other, are identical in the two cases. The painting and marks are also the same.

NOTE.—The two sizes of faking-boxes given above are issued to life-saving stations at the present time, and correspond to the two sizes of shot-lines issued.

III. FAKING-BOX C (large, square).

(Plate XXXIII.)

1. *Description.*

		Inches.	Centim'rs.
External dimensions	Length	24.0	= 60.959
	Width	24.0	= 60.959
	Depth	12.8	= 32.511
Internal dimensions	Length	22.9	= 58.165
	Width	22.9	= 58.165
	Depth	12.3	= 31.241

2. *Weight.*

	Lbs.	Kilos.
Average weight, empty	33	= 14.968
Average weight, with "linen line No. 5," about	57	= 25.854

3. *Materials.*

The materials for this box are the same as those used for the preceding boxes.

4. *Nomenclature and dimensions.*

		Inches.	Centim'rs.
1 top	Length	24.0	= 60.959
	Width	24.0	= 60.959
	Thickness	.5	= 1.270
2 side pieces, same size	Length	24.0	= 60.959
	Width	12.3	= 31.241
	Thickness	.55	= 1.397
2 end pieces, same size	Length	24.0	= 60.959
	Width	12.3	= 31.241
	Thickness	.55	= 1.397
1 "false bottom"	Length	22.6	= 57.403
	Width	22.6	= 57.403
	Thickness	.6	= 1.524

Frame for faking-pins.

		Inches.		Centim'rs.
2 side pieces, same size	Length	25.8	=	65.531
	Width	3.7	=	9.398
	Thickness	.9	=	2.286
2 end pieces, same size	Length	24.75	=	62.864
	Width	4.3	=	10.922
	Thickness	.9	=	2.286

Faking-pins.

			Inches.		Centim'rs.
40 pins, same size	Total length		12.4	=	31.495
	Body	Length	11.5	=	29.209
		Greatest diameter	1.0	=	2.540
		Least diameter	.35	=	.889
	Screw	Length	.9	=	2.286
		Diameter	.7	=	1.778
2 cleats for rope handles, same size		Length	6.2	=	15.748
		Width	2.0	=	5.080
		Thickness	1.4	=	3.556
2 handles, hemp rope		Length	18.0	=	45.719
		Diameter	.5	=	1.270

2 hasps, metal, for fastening box to frame.

IV. FAKING-BOX D (small, square).

(Plate XXXIV.)

1. *Description.*

		Inches.		Centim'rs.
External dimensions	Length	16.0	=	40.639
	Width	16.0	=	40.639
	Depth	12.8	=	32.511
Internal dimensions	Length	14.9	=	37.845
	Width	14.9	=	37.845
	Depth	12.3	=	31.241

2. *Weight.*

	Lbs.		Kilos
Average weight, empty	18	=	8.164
Average weight, with "linen line No. 3½," about	26	=	11.792

3. *Materials.*

The materials for this box do not differ from those of the preceding boxes.

4. *Nomenclature and dimensions.*

		Inches.		Centim'rs.
1 top	Length	16.0	=	40.639
	Width	16.0	=	40.639
	Thickness	.5	=	1.270
2 side pieces, same size	Length	16.0	=	40.639
	Width	12.3	=	31.241
	Thickness	.55	=	1.397
2 end pieces, same size	Length	16.0	=	40.639
	Width	12.3	=	31.241
	Thickness	.55	=	1.397

			Inches.		Centim'rs.
1 "false bottom"		Length	14.55	=	36.956
		Width	14.55	=	36.956
		Thickness	.6	=	4.064

Frame for Faking-pins.

2 side pieces, same size		Length	18.0	=	45.719
		Width	3.7	=	9.398
		Thickness	.9	=	2.286
2 end pieces, same size		Length	16.9	=	42.925
		Width	4.35	=	11.049
		Thickness	.9	=	2.286

Faking-pins.

24 pins, same size	Total length		12.4	=	31.495
	Body	Length	11.5	=	29.209
		Greatest diameter	1.0	=	2.540
		Least diameter	.35		.889
	Screw	Length	.9	=	2.286
		Diameter	.7	=	1.778
2 cleats for rope-handles, same size		Length	6.2	=	15.748
		Width	2.0	—	5.080
		Thickness	1.4	=	3.556
2 handles, hemp rope		Length	18.0	=	45.719
		Diameter	.5	=	1.270

2 hasps, metal, for fastening box to frame.

NOTE. The square faking-boxes C and D do not differ materially in construction from boxes A and B. They are experimental boxes.

PART III.

RECORD OF EXPERIMENTS.

The experiments are divided into two series; the first series comprising those made at Springfield, Mass., in the autumn of 1877; the second, those made at Sandy Hook, N. J., in the spring of 1878.

CHAPTER I.

FIRING-GROUNDS.

I. FIRING-GROUND AT SPRINGFIELD, MASS.

(Plate XXXVII.)

Considerable difficulty was experienced in finding a suitable firing-ground in convenient proximity to the National Armory. The grounds possessed by the United States Government afforded too limited a range to be of any practical utility. The government for its own purposes used ranges over water in experimental firing; but though the ultimate object of the present trials was to determine the best means of throwing lines over an intervening space of water, it was especially undesirable during these trials to have such an inconvenient obstruction between the initial and objective points of the firing.

Some of the chief requisites of a good firing-ground for making experiments in throwing lines are:

1. That it should present an adequate range.
2. That it should be nearly level.
3. That there should be no obstacles to interfere with the attainment of a good view of the shot and line throughout the trajectory, nor with taking up the line after firing. This condition rejects a range over water not only on account of wetting the line, thereby increasing its weight and rendering the result of the subsequent shot incomparable with one made with the dry line, but also by increasing the physical difficulties of taking up the line and replacing it in the faking-box.

It also rejects ground covered with briers or other prickly plants or shrubs whose prickles penetrate and break off in the line when it is drawn through them, thus rendering the handling of the line both difficult and painful.

4. That the extent of the range should be great enough to enable the observer to note the point of fall of those shot that break the line and pass far beyond the limits which they would attain if the line remained intact, in order that the shot may be easily recovered for subsequent use.
5. That human habitations should not be in or near the plane of fire.

After some time spent in prospecting for a spot suited to the object in view, one was selected about one mile from the city of Springfield, Mass., but still within the city limits. It consisted of two strips of meadow-land nearly level for about 700 yards; the extremity of the range

farthest from the gun having the greater elevation. The ground presented a very clear range of 687 yards between the two tracts of timber land at its extremities.

The disadvantages were, that the firing had to be done over a much-traveled road, that the land closely adjacent was often occupied by laborers, that the nearness of the city enabled many idlers, especially boys, to congregate in the vicinity of the plane of fire. The delays and annoyances due to these causes were many and oftentimes very troublesome. All the appurtenances of the range had to be set up and removed at each visit to prevent their wanton destruction by tramps or thoughtless boys.

No difficulty was experienced in obtaining the necessary permission from the municipal authorities to fire within the city limits and over the roadway. They merely required that sentinels should be stationed on the road to warn passers by, in order to prevent accidents.

The land occupied was owned by Mr. E. W. Bond, president of the Massachusetts Mutual Life Insurance Company, and Mr. James Kirkham, president of the First National Bank of Springfield, both of whom very kindly and generously allowed it to be used without asking for any compensation.

At the firing point a gun platform was constructed to avoid the tearing up of the ground due to the recoil in continued firing.

This platform was 8 feet long and 6 feet wide, made of 2-inch deck plank spiked down upon 4 sleepers. The sleepers were 8 feet long, with a cross-section of 10 inches square, and were bedded in the ground flush with the surface. Immediately in front of the center of the platform was driven the initial stake from which the range was measured. The muzzle of the piece was placed directly over this stake in firing. From this point the range was laid off by means of a tape-line 100 feet long; and a stake, with its distance in yards from the origin marked upon it, was driven down at 100 yards, and at each additional hundred yards from the initial point. Intermediate stakes were driven at intervals of 25 yards between those which designated the 100-yard points. This arrangement greatly facilitated the measurement of the ranges of the shot.

Later a second range was laid out from the same origin, but so inclined as to clear the point of the woods, in which several shot had been lost by the breaking of the lines. This range was marked at each hundred yards by an appropriately-numbered stake.

The ranges were remeasured, to preclude any possibility of error.

To the right and rear of the gun platform was erected a shelter 7 feet long and 6 feet high, made of 10-inch timber, to screen the firing party when testing new guns with heavy charges. Every precaution was taken to prevent accidents. The guns were always fired with a lanyard and service primer. When firing, range flags were placed at the 300, 400, and 500-yard stakes, to mark the line of fire. In *every case* the gun was pointed so as to bring the plane of fire to coincide with the line of flag-staves. Twenty-five yards to the right of the 200-yard stake was placed a Casella anemometer, to measure the approximate surface velocity of the wind. This instrument was placed a little over five feet from the ground. It occupied a clear space, removed from any obstructions that would modify the velocity of the surface current of air. The direction of the wind with reference to the line of fire was estimated from the position assumed by a vane five feet long, situated at the same spot as the anemometer.

General method of firing.

The practice usually observed in firing was as follows:

1. To set up and align the range flags.
2. To place the anemometer in position and take the initial reading.
3. To place the faking-box containing the line in position for firing.
4. To point the gun so that the vertical plane through its axis would coincide with the line of flags as closely as possible.
5. To charge the piece with a cartridge containing the powder.
6. To attach the line to the shot and insert it in the piece.
7. To give the proper elevation.
8. To prick the cartridge and insert the friction primer.
9. To fire the gun.
10. To take the reading of the anemometer.
11. To measure the range. The distance from the nearest stake to the point where the shot fell is measured with a pole ten feet long, and then reduced to yards, and added *algebraically* to the number of yards on the stake.
12. The deviation of the shot to the right or left of the line of fire is measured in feet with the same pole.
13. The bowing or drift of the slack of the line from the plane of fire at the 300-yard stake is measured.

II. FIRING-GROUND AT SANDY HOOK, N. J.

The second series of experiments were conducted at the ordnance "proving-ground" at Sandy Hook, N. J.

Permission to use these grounds was granted by General S. V. Benét, Chief of Ordnance, and Col. S. Crispin, constructor of ordnance, United States Army.

A range was laid out along the sandy beach, carefully measured, and marked by stakes, as in the preceding instance at Springfield, Mass.

Range flags were used to indicate the plane of fire.

A gun platform, 13 feet square, was placed at the firing point, which, though it allowed the gun and carriage to recoil more in firing, was a necessity where continued experiments are carried on in the yielding sand.

A Casella anemometer was mounted on a staff 5 feet high and placed about 20 yards to the right of the 200-yard stake, for the purpose of obtaining the velocity of the wind at the surface of the ground.

A vane was placed at the same point, to determine the direction of the wind with reference to the plane of fire.

The velocity of the wind at an altitude of about 50 feet above the surface of the ground was taken, whenever possible, at the office of the Ordnance Board, a short distance in rear of the firing point.

On a subsequent page are given the velocities of the wind during the hours of experimental firing, as indicated by the self-registering apparatus in the office of the signal-service observer.

The two instruments last referred to are Robinson anemometers, and are by no means so delicate in their indications as the Casella air meter used for the surface velocities.

In the tables giving the results of the firings, the long arrow, running the whole length of the column, marked "Wind, direction," represents the intersection of the plane of fire with the surface of the ground and the direction in which the guns were pointed.

The short arrows indicate the direction of the wind with reference to this line.

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1).

	Material.	Braided lines — Length. Yards.	Meters.	Diameter. Inchs.	Mi… me…
	Linen No. 1	600	548 +	0.22	5
	do	600	548 +	0.22	5
	Italian hemp No. 1	700	640 +	0.13	3
	Linen No. 1	600	548 +	0.22	[illegible]
	do	600	548 +	0.22	[illegible]
	do	600	548 +	0.22	[illegible]
	do	600	548 +	0.22	[illegible]
	Italian hemp No. 1	700	640 +	0.13	[illegible]
	do	700	640 +	0.13	[illegible]
	do	700	640 +	0.13	[illegible]
	Linen No. 1	600	548 +	0.22	[illegible]
	Italian hemp No. 1	700	640 +	0.13	[illegible]
	do	700	640 +	0.13	[illegible]
	do	700	640 +	0.13	[illegible]
	Linen No. 2	600	548 +	0.22	[illegible]
	Italian hemp No. 2	700	640 +	0.13	[illegible]
	do	700	640 +	0.13	
ed	Linen No. 2	600	548 +	0.22	
	Italian hemp No. 2	700	640 +	0.13	
	Linen No. 1	600	548 +	0.22	

ards and decimal parts of a yard.

1. *Synoptical transcript of notes from the firing record.*

3-INCH M. L. RIFLED MORTAR—BRONZE.

Date.	No. of round.	
1877.		
Sept. 22	1	Rifle projectile.—Gas entered axial cavity notwithstanding sabot, and blew the cap off; cutting the retaining-screw entirely off, carrying the knot, rubber tube, and washer out at the front end of the shot. When the resistance of the line drew the rubber tube and knot back, the former caught on the forward end of the shot, introverting a portion of the tube and cutting off the line. About 20 yards of line carried out. Rubber tube found about 150 yards in front of gun. A good line-shot, ranging 723 yards and striking a tree 40 feet from the ground. Projectile recovered.
	2	Rifle projectile.—The cap was not blown off, nor was any trace of gas found in the axial cavity. The shot and line were recovered; the rotation of the shot due to the rifled motion twisted the line badly. The line assumed a spiral fusiform shape in rear of the projectile; the spirals near the shot being very small and increasing in amplitude with their distance in rear of it, until a point within about 50 yards of the faking-box was reached, from which point to the box the amplitude of the spirals decreased. This tapering of the spirals in rear of the shot increased greatly the resistance of the air and diminished the range.
	3	Rifle projectile.—Line carried out 25 or 30 yards; end appeared as if burned off; shot lost. One sabot recovered.
Sept. 27.	4	Rifle projectile.—Copper-wire rope interposed between shot and line, broke. Forty yards of line carried out. Gas entered axial cavity and started the brazing of the cap. Projectile rotated about its shorter axis and struck upon its side.
	5	Rifle projectile.—The cap being lost the line was knotted over a lead washer and inserted in the gun point first, with two sabots to rest upon and prevent the gas burning off the knot. The shot was fired base first, took the rifled motion and when it felt the strain upon the line it reversed, but retained the rifled motion and undulated up and down in the trajectory. The line was twisted as before.
	6	Rifle projectile.—This shot was placed in the gun like the preceding one and fired base first, but when it reversed it did not proceed point foremost, but continued to rotate about its shorter axis. The rotation of the shot twisted the line.
Oct. 6.	7	Smooth-bore projectile.—The bowing or drift of the shot-line from the line of fire at the 300-yard stake was 129 feet to the right. The shot kept point foremost after reversing and the resistance of the line kept it so.
	8	Rifle projectile.—Used one wooden and one Cordes sabot. Gas penetrated axial cavity, burning off the line, which was found to be still burning when examined. Shot lost. Range unknown. Action in trajectory unknown.
	9	Smooth-bore projectile.—This shot rotated about its shorter axis during its whole flight; the line did not experience resistance enough to keep the shot point first. Wind directly across line of fire, velocity about 6.37 miles per hour. The line bowed 226 feet to the right at the 300-yard stake.
Oct. 10.	10	Rifle projectile.—The shot was fired base first. The base was turned off, forming a frustum of a cone, and the longitudinal groove for the line (along the side of the shot) was partially filled with lead. The escape of gas in firing cut out lead. The shot rotated about its shorter axis in the first part of the trajectory and kept point first during the latter part of its flight. Shot penetrated two feet into

1. *Synoptical transcript of notes from the firing record*—Continued.

3-INCH M. L. RIFLED MORTAR—BRONZE—Continued.

Date.	No. of round.	
1877.		the ground in falling. Line twisted and lay in loose coils in the vicinity of the point where the shot struck. The line bowed 68 feet to right of 300-yard stake.
Oct. 10	11	Smooth-bore projectile.—Line ran out beautifully. Bowing of line. 14 feet to right of 300-yard stake. Escape of gas through rifles diminishes range.
	12	Smooth-bore projectile.—Bowing of line, 33 feet to left of 300-yard stake. Velocity of wind probably greater than given, as the interval between readings in this case was 63 minutes, and the wind was increasing all the time. Escape of gas through the rifles affected the range.
Oct. 13.	13 14	Smooth-bore projectiles.—Line burnt off in each case and shot lost. Range uncertain, probably over 800 yards. Both shot rotated about shorter axis. Faking-box placed 9 feet to left of platform on windward side. Line burned off in loop in each case; end of line on fire when examined. The length of the powder-charge was such that it greatly increased the gas-escape through the grooves.
Oct. 24	15	Smooth-bore projectile.—Bowing of line, 13 feet to right at the 300-yard stake. The line was all carried out and the end dragged 115 feet from the box towards the front. Shot penetrated earth 18 inches. Reading of anemometer uncertain, not properly adjusted; but result varies but little from the truth.
	16	Smooth-bore projectile.—Bowing of line, 9.5 feet to left at 300-yard stake. The line was all carried out, the loose end being dragged to the front a distance of 128 feet. Shot buried 2 feet in the ground. Projectile rotated about its shorter axis three or four times in the first part of the trajectory. Wind-velocity 5.2 miles per hour.
Nov. 3	17	Smooth-bore projectile.—The shank broke off close to base of shot. It broke when the shot reversed and brought the strain upon the shank, which accidentally had been made of steel instead of wrought iron. Shot lost. About 100 yards of line carried out.
	18	Smooth-bore projectile.—Shot with very long shank (10 inches). Faking-box to left of gun-platform. Bowing of line, about 200 feet to right at 300-yard stake. Wind, 10.864 miles per hour.
12	19	Smooth-bore projectile.—Shot carried away 75.5 feet of hemp line, which probably broke at or near a spot that had been partially cut through previously by whipping against edges of box. Shot recovered. Range over 900 yards.
	20	Smooth-bore projectile.—Bowing, 70 feet to right at 300-yard stake. Shot had 10-inch shank.

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of 2 inches.

Length.		Bra Diam
Yards.	Meters.	Inch.
700	640 +	0. 13
700	640 +	0. 13
600	548 +	0. 22
600	548 +	0. 22
700	640 +	0. 13
700	640 +	0. 13
700	640 +	0. 13
700	640 +	0. 13
700	640 +	0. 13
700	640 +	0. 13
700	640 +	0. 13
700	640 +	0. 13
700	640 +	0. 13
700	640 +	0. 13
700	640 +	0. 13
600	548 +	0. 22
700	640 +	0. 13
700	640 +	0. 13
600	548 +	0. 22

1. *Synoptical transcript of notes from the firing record.*

GUN A, 2 INCHES CALIBER.

Date.	No. of round.	
1877.		
Nov. 3	1	Line broke. Shot carried away 22$\frac{3}{4}$ yards of line. The detached portion of the line was partially cut through in two places; one cut or break was 4$\frac{3}{4}$ yards from loose end (or 18 yards from projectile), and extended half-way through the line; the other was a slight cut nearer the shot and not so deep. A few yards of the line was faked upon the ground in about 18-inch lengths. The vibrations of the line were violent, whipping badly across the edges of the box and cutting off the line. Projectile recovered.
	2	The bowing of the line at the 300-yard stake was 119 feet, and was a little greater at the 400-yard stake. Velocity of wind, 9.71 + miles per hour.
	3	Broke linen line No. 1. Shot lost.
	4	Bowing of the line, 136 feet to the right of the 300-yard stake. Velocity of the wind, 10.2 miles per hour. Line knotted badly by some of the fakes slipping under others. The line was cut half off about 20 yards from the projectile by striking the edge of the faking-box. The vibrations of the line were so violent as to split the end of the box 4 inches from the top.
	5	Line burnt off by flames of gas escaping around shot through the windage. Burnt off at point of attachment to shot. Projectile lost. Range over 1,000 yards. Faking-box placed 15 yards in front of the gun.
7	6	Shot turned over and over about its shorter axis.
	7	Projectile rotated three or four times about its shorter axis in a plane nearly horizontal and then oscillated up and down during the remainder of its flight, keeping its head or point to the front.
	8	Wind, light and variable; changing direction often.
	9	A knot in the line from the fakes slipping under each other and looping.
	10	Bowing of line, 24 feet to the left at the 300-yard stake. The bore of the gun noticed to be slightly enlarged.
	11	Bowing of the line, 22 feet to the left at the 300-yard stake.
	12	Bowing of the line, 54 feet to the left at the 300-yard stake.
	13	Bowing of the line, 67 feet to the left at the 300-yard stake.
	14	Italian hemp line No. 2. Broke near box. No line carried out. Probable range, over 750 yards. Projectile rotating about shorter axis.
	15	Same remark as preceding shot.
	16	Linen line No. 2. Bowing of line, 50 feet to the left at the 300-yard stake.
12	17	Bowing of line, 23 feet to the right at the 300-yard stake. Elevation of piece too great. Trajectory too high, requiring more line than was necessary for the range attained. The resistance of the air on the falling line was so great that, when descending, the projectile appeared to fall almost vertically for quite a distance.
	18	Line broke. Projectile lost.
	19	Line (linen No. 1) broke. Initial velocity of projectile too great. The rapidity of vibration of the rope in running from the faking-box was so violent as to knock out the upper part (4″ wide) of one end of the box, though the corners were dovetailed together. The fakes in the rope were too long to be used with projectiles having such great initial velocity as this shot. The sabot (Cordes) was a failure, the gas passing it and entering the axial cavity; the pressure of the gas inside the shot was so great that the head was blown off and lost. A portion of the shot and the sabot were recovered.

MASS.

of 2.5 *inches.*

laterial
np No. 2........
np No. 1........
....
....
n ....
....
2 ....
3 ....
....
....
....
2...............
....
np No. 2.......
2 (in small box)
np No. 2.......

Mass.

of 2.5 inches.

Material	Length.		Braided [illegible] Diame[illegible]
	Yards.	Meters.	Inches.
np No. 2	700	640. +	0. 13
np No. 1	700	640. +	0. 13
....	700	640. +	0. 13
....	700	640. +	0. 13
1	600	548. +	0. 22
....	600	548. +	0. 22
2	600	548. +	0. 22
3	800	731. 5	0. 10
....	800	731. 5	0. 10
....	800	731. 5	0. 10
....	800	731. 5	0. 10
2	600	548. +	0. 22
....	600	548. +	0. 22
np No. 2	700	640. +	0. 13
2 (in small box) ..	600	548. +	0. 22
np No. 2	700	640. +	0. 13

1. *Synoptical transcript of notes from the firing record.*

GUN A.—2.5 INCHES CALIBER.

Date.	No. of round.	
1877.		
Nov. 21	1	No remarks.
	2	Line broke; shot carried away 90 feet of line; shot recovered. Range, over 900 yards.
	3	Forty-six feet of linen line (No. 1, diameter 0''.22) tied, one end to shot and the other to the Italian hemp line No. 1, to receive the first shock of discharge. When fired the knot came loose with a noise like the explosion of a friction primer.
	4	The bowing or drift of the line from the line of fire was 110 feet at the 300-yard stake.
	5	Linen line No. 1 cut off at 105 feet from the shot by whipping against the edge of a slight notch in the side of the faking-box; shot and attached portion of line recovered. Range, over 900 yards.
	6	Bowing of line at 300-yard stake, 71 feet.
	7	Bowing of line at 300-yard stake, 84 feet.
Nov. 22	8	New braided line, "No. 3½ linen, bleached." Deviation of line from plane of fire, 75 feet at 300-yard stake and 86 feet at 400-yard stake. About 775 yards of line carried out of box. Six knots found in line; these were small loops formed by some of the fakes slipping under others and being drawn into a knot by the rapid vibrations of the line. The projectile penetrated two feet into the ground. The gun and bed turned upside down after sliding from the platform, due to the surface of the latter being 6 inches above the ground in rear of it.
	9	Line broke; shot carried away 27.5 yards of line. A small knot found 20 yards from projectile. The range was about 1,000 yards, deviating slightly to the left of the line of fire. The shot struck a tree, breaking the shank off at the beginning of the screw-thread; both shot and line recovered. The shot and attached piece of line described an undulatory path, in a vertical plane.
	10	Line broke; shot carried away 21 yards of line. The line (the detached portion) was found to be nearly cut through at 13 yards' distance from the shot, probably due to a knot which pulled out before the line was severed: a small knot was found 20 yards from shot. The range was about 40 yards greater than the preceding shot; the deviation was slightly to the right; the projectile rotated horizontally about its shorter axis.
		In this and the preceding case the frayed ends of the broken line were 1''.5 long, appearing as if combed. This length (1''.5) was greater than any hitherto found to occur with any line used; the braided lines having usually broken sharply off without leaving the ends frayed more than a fraction of an inch. Several knots were also found in different parts of the line. The faking-box testified to the violent vibrations of the line in running out, by the indentations made in the edges, sides, and ends of the box by the line. From these facts it would appear probable that some of the fakes caught each other and looped, and were drawn sharply against or across the edge of the box, forming a knot whose resistance was sufficient to cause the severance of the line.
Nov. 27	11	Line drifted 353 feet to left of plane of fire at 400-yard stake. All the line (751 yards) was carried out, together with part of piece of old line (0''.22 in diameter) which had been attached to the shot-line. The shot in the last portion of the trajectory fell in a line closely approaching a vertical; in fact, it appeared from the firing-point as if suspended by the line. After the projectile had passed over about one-half of its descent, the light line, becoming slack, was

1. *Synoptical transcript of notes from the firing record*—Continued.

GUN A.—2.5 INCHES CALIBER—Continued.

Date.	No. of round.	
1877.		drifted off by the wind, whose velocity near the upper part of the trajectory was much greater than that near the surface of the ground. Six small knots or loops were found in the line. The great bowing of the line was due to its lightness, the high angle of elevation, the velocity of the wind high above the surface of the plain, and the fact that when the shot was descending there was little or no longitudinal strain.
Nov. 27	12	Line broke: shot carried away 37 yards of linen line No. 2: both recovered. Faking-box is too long for use with this initial velocity for projectile. The vibrations of the line were very violent: the box showed indentations where the faked loops had been sunk into the wood by the whipping.
	13	With six ounces of Hazard musket powder the base of the projectile (L. 3), experimental No. 11, was flush with the face of the muzzle.
	14	Shot carried away 28 yards of line (Italian hemp No. 2).
	15	Linen line No. 2: The line bowed 65 feet to the left of the 300-yard stake. This line was faked in the small boxes "B," filling two of them. By placing in this size box the amplitude of the lateral vibrations is much diminished.
	16	Italian hemp line No. 2: The bowing measured at the 300-yard stake was 124 feet to the left; angle of elevation too great for the wind that was blowing.

	Braided	
ngth.		Dia
.	Meters.	Inches
0	640 +	0. 145
0	548 +	0. 215
0	548 +	0. 235
0	548 +	0. 235
0	548 +	0. 32
0	548 +	0. 26
00	548 +	0. 28
00	640 +	0. 19
00	548 +	0. 32
00	548 +	0. 26
00	548 +	0. 23
00	548 +	0. 23
00	548 +	0. 21
00	640 +	0. 19
600	548 +	0. 28
700	640 +	0. 14
600	548 +	0. 22
600	548 +	0. 21
600	548 +	0. 21
700	640 +	0. 26
700	640 +	0. 2
600	548 +	0. 3
600	548 +	0. 2
700	640 +	0. 1
700	640 +	0. 1
700	640 +	0. 1
700	640 +	0. 1
700	640 +	0. 1

. = Water-proof.

Synoptical transcript of notes from the firing record.

GUN A.—CALIBER, 3 INCHES.

Date.	No. of round.	
1878.		
May 14	1	Italian hemp line No. 4½ emptied into a pine packing-box before firing. Lateral vibrations of line sufficient to loosen the nails in both ends of box. End of line found in crack between end and side of box. The line was probably cut off by being drawn violently across sharp corners and through the crack—uncertain, may have been broken. Shot ranged 850 yards, carrying 27 yards of line with it.
	2	Base of projectile flush with the face of muzzle. Vibrations of line knocked the bottom and end out of the faking-box (A).
	3	Line (hemp No. 7) broken squarely off. Sixteen yards of line left attached to shot, which struck the ground 980 yards from the piece. The vibrations of the line split the end and side of the faking-box (A) into 4 or 5 pieces. The two faking-boxes above mentioned were rendered useless for further service in transporting lines.
	4	No remarks.
	5	Line (hemp No. 10) emptied into the two faking-boxes (A) mentioned in rounds 2 and 3. [These boxes will be referred to in following shots as "old faking-box A," &c. They were used (or at least one of them) until the 14th round to avoid breaking up new boxes.] Bevel on rear end of shot extended beyond face of piece.
	6	Line (No. 8) emptied into 2 old faking-boxes A, and part left in box B. Half of bevel at base of shot exposed beyond muzzle of piece.
	7	Line (No. 9) put in 2 old faking-boxes A for firing. Half of bevel on rear of shot exposed.
	8	Line in one old box A. Base of shot flush with muzzle of piece.
	9	Line (No. 10) in 2 old boxes A.
	10	Line (No. 8) in 2 old boxes A. One electric primer failed to explode.
	11	Line (No. 7) in 1 old box A. Could not tell whether the line was cut on the broken box or was broken by vibrations; 25 yards of line carried off by shot. Range, 704 yards; deviation, 5 yards to right.
	12	Line (No. 7) in 1 old box A.
	13	Line (No. 6) in 1 old box A. The gun was probably not pointed properly by the assistant. The line caught on the broken end of the box, which may have changed the direction of the shot somewhat, but not enough to account for the marked deviation of the shot. The box was on the right of the gun. From the insignificant difference between the deviation of the shot and the "drift," as measured from the 300-yard stake, the writer is inclined to the opinion that the gun was not properly pointed. The assistant did not recollect whether he verified the alignment of the gun or not.
	14	Line (No. 5) in 1 old box A. In the above cases the line was emptied from their own faking-boxes into those designated in this transcript of remarks. Wind at office at end of 14th round, 20.6 miles per hour.
May 21	15	Line put in tray before firing. The line (No. 9, linen) was fired from the coil as received from the manufacturer. The line run out in a fusiform helix, each coil putting one twist in the line. For this and the subsequent rounds the *Casella* air meter for determining the surface velocity of the wind was placed 50 yards in front of the gun instead of 200 yards in front, as before.
	16	Line emptied into tray. Nearly all of the line carried out.
	17	Line emptied into tray. Three tiers of fakes left in tray.
	18	Line emptied into tray. Line broke 18¼ yards on shot. Projectile rotated about shorter axis; shank slightly bent when shot struck the ground. Range, 920 yards.
	19	Line emptied into tray before firing.

1. *Synoptical transcript of notes from the firing record*—Continued.

GUN A.—CALIBER, 3 INCHES—Continued.

Date.	No. of round.	
1877.		
May 21	20	Line emptied into tray before firing. In faking, about a dozen coils had been placed in the bottom of the box before proceeding with the faking; when ready to fire, these loose coils were on top of course, and not being faked in small lengths, allowed excessive amplitude of vibration at the instant of discharge. The line broke short off, not even taking out all the coils. The fakes below were undisturbed. Range of shot, 930 yards, carrying 6¾ yards of line with it.
	21	Line put in tray before firing.
	22	Line put in tray before firing, in three lots. [Was faked in three boxes.]
	23	Line put in tray before firing.
	24	Line put in tray before firing. The above 24 shots were fired with "electric primers" for convenience.
May 22	25	Fired out to sea. Estimates of range made in this and three succeeding shots by 4 different persons, all accustomed to estimating distances on the water. The recorded range (300 yards) is below all estimated ranges given, so as to be sure to fall within the limits of truth. The writer places little faith in estimated distances, as they generally are very inaccurate, especially upon water.
	26	Fired out to sea. Line wet, rough, stiff, and covered with sand. It lay in loose coils on the beach where it had been hauled in "hand-over-hand" through the water and sand. Action of the line pretty good; a few snarls were seen, but they were very small. Range variously estimated from 275 to 300 yards by those present.
	27	Fired out to sea. Same line hauled in and placed on the sand in two loose coils. Line wet and sandy, kinked badly. Range variously estimated from 180 to 275 yards; recorded as between 180 and 200 yards.
	28	Fired out to sea. Line hauled in and placed in one coil on the beach. All kinks or snarls removed. Action of line very good, no snarls. Estimated range "about same as last shot," but recorded as 175 yards. Absorption of water by the line evidently tells more or less upon the range.
		"Service primers, long," used for last four shots. The same line (Italian hemp No. 4½) and projectile were used in firing the four shots to sea. Heavier charges of powder would have been used, but none heavier happened to be at hand at the time. The object of the shot was more to witness the action of the line when wet and sandy than to obtain any definite range. Action of gun-carriage on sandy beach very good.

HOOK, N. J.

[..]liber 2 inches.

[..]. Boston, Mass.]

Material.	Number.	Length Yards.	
[..]lian hemp	3½	700	
[..]lian hemp. No. 2 (old.)	4½	700	
[..]nen, No. 1 / [..]lian hemp	7 / 3½	700	
[..]nen	4½	700	
do	5	700	
[..]alian hemp. No. 2 (old)	4½	700	
[..]inen. No. 1 (old)	7	600	
[..]inen. No. 2 (old)	7	600	
[..]talian hemp	4	700	
do	4½	700	
do	5	700	
do	6	600	
do	7	600	
[..]inen	3½	700	
[..]talian hemp	6	600	
do	4½	700	
[..]inen. W. P	4	700	
[..]inen	3½	700	
[..]talian hemp	5	700	
do	7	600	
[..]talian hemp. W. P.	4	700	
do	4	700	
[..]inen. W. P	4	700	
[..]inen	4	700	
[..]ark linen	4	700	

[..] of the 200-yard stake.

[..]Water-proof.

1. *Synoptical transcript of notes from the firing record.*

GUN B.—CALIBER, 2 INCHES.

Date.	No. of round.	
1878.		
March 8	1	For this and the four succeeding rounds the smooth-bore bronze gun B was mounted upon a block of wood weighing 48 pounds. Italian hemp line No. 3¼ broke close to the shot. Projectile ranged over 700 yards, and was lost in a wooded tract of land.
March 16	2	Shot had no cap and was placed in the gun with its base toward the muzzle. One ½-inch wooden sabot used. A good line shot.
	3	No cap on shot; one sabot used; base of shot toward muzzle. About 100 yards of old linen line (diameter 0''.22) used, between the shot and hemp line No. 3¼, to receive the first shock of the discharge. The large line broke—probably burned off inside the shot by the gas which entered the axial cavity.
	4	Lead projectile "upset" slightly by the shock of discharge. Only one rotation of shot about shorter axis could be detected. Flight of shot and action in the trajectory excellent. Bore of gun found to be "leaded," due to the upsetting of the shot and the consequent friction.
	5	Same projectile used. It had probably been bent slightly by striking the ground, and had to be filed a little in order to enter the bore.
May 11	6	Velocity of wind 18.18 miles per hour as indicated by a Robinson anemometer upon the ordnance office at Sandy Hook. This instrument was about 50 feet above the surface of the ground and 200 yards from the firing point.
May 13	7	Velocity of wind 15 miles per hour by office anemometer just before experiments began. Base of shot flush with the face of the muzzle when the gun was loaded. Wind variable.
	8	Base of shot flush with face of piece. Wind almost calm at instant of firing.
	9	Base of shot flush with face of piece. Wind increasing.
	10	Base of shot flush with face of piece.
	11	Base of shot flush with face of piece. Vibrations of line started the dovetailing in end of faking-box.
	12	Base of shot flush with face of piece.
	13	Base of shot flush with face of piece. Powder charge compressed in loading. Wind at office 12.4 to 13.9 miles to 20 miles per hour as taken within 10 minutes after round 13 was fired, from the anemometer on the building. Wind very variable during the whole forenoon.
	14	Base of shot flush with face of piece. Projectile rotated about its shorter axis throughout the greater part of the trajectory. Vibrations of line No. 3¼ started dovetailing of box D on side next to the gun.
May 20	15 16 17 18 19 20	Readings of Casella anemometer not taken at 200-yard stake—no time. Direction of wind variable within small azimuthal limits—general direction, "head wind." Velocity of wind at office (Robinson anemometer, elevation about 50 feet) varied from 18 miles to 24 miles per hour; wind came in gusts; weather damp, and showery part of the time. S. I. Kimball, general superintendent United States Life-Saving Service, and Capt. J. H. Merryman, United States Revenue Marine, inspector of that service, both present.
May 22	21	Fired directly against the wind and out to sea. Line either cut on button of box or broken; appeared to be cut; uncertain. Shot lost.
	22	Fired out to sea directly against wind. Range estimated by those present to be from 400 to 450 yards; true range unknown; lowest estimate inserted in table. Velocity at office 20 miles per hour.
May 23	23	Reading of anemometer uncertain; probably too great. Shot rotated several times. Line in tray.
	24	Line emptied into tray before firing. Shot rotated in horizontal plane.
	25	Line emptied into tray before firing.

ok, N. J.

2.5 *inches.*

os., Boston.]

rial.	Number.
n No. 2..	7
No. [illegible], used in first series of experiments, was used in this series of experiments.	Same line used for twenty shots.
rds linen.	7
hemp...	3½
....	7
....	3½
....	3½
hemp....	4½
....	4½
....	5
....	6
....	7

ↄK, N. J.

2.5 *inches.*

os., Boston.]

erial.	Number.	Length. Yards.	Meters.
n No. 2..	7	600	548 +
No. 2, used in first series of experiments, was used in this series of experiments.	Same line used for twenty shots.	These shots made to compare merits of the powders used.	
ds linen.	7	150	640 +
hemp...	3½	700	
....	7	150	
....	3½	700	640 +
....	3½	700	640 +
hemp....	4½	700	640 +
....	4½	700	640 +
....	5	700	640 +
....	6	600	548 +
....	7	600	548 +

1. *Synoptical transcript of notes from the firing record.*

GUN C.—CALIBER 2.5 INCHES.

Date.	No. of round.	
1878.		
May 6.	1	Reading of anemometer uncertain, instrument not leveled. The gun was discharged by means of "service friction primers, short," from the 1st to the 6th round, both inclusive.
	2	Anemometer reading uncertain.
	3	Gun probably aimed to the right.
	4	No remarks.
	5	No remarks.
7	6	No remarks.
	7	"Service primer, long;" one failed to explode. These primers were used from the 7th to 20th round, both inclusive. Lanyard used in connection with these primers.
	8	A couple of fakes caught and knotted.
	9	Two small knots in line.
	10	One large knot; fakes got looped over each other and carried out a long knot. Velocity of wind 15 miles per hour, by instrument on top of office (about 50 feet above the ground), distant about 200 yards from firing point.
	11	No remarks.
	12	Vibrations of line split the end of the faking-box next to the gun.
	13	No remarks.
	14	No remarks.
	15	Velocity of wind 18.95 miles per hour, by instrument on office.
8	16	Wind very light.
	17	Wire pulled out of primer, and the gun "hung fire."
	18	Two knots in line, one small and one large; fakes caught each other.
	19	One large knot in line; fault of man who faked the line.
	20	Loosened end of faking-box. Line whipped out in knots, but all the knots came out while the line was in the air.
10	21	Line No. 3½ (Italian hemp) broke near the knot where it was tied to linen line No. 7. A piece of new linen line No. 7, 150 yards in length, was fastened to the shot to receive the first shock of the discharge, and the other end was made fast to Italian hemp line No. 3½. The small line broke, and the shot ranged 550 yards, carrying the 150 yards of heavy line with it. The shot fell 20 feet to the left of the plane of fire. A careful examination of hemp line No. 3½ disclosed the fact that it was quite brittle in fiber, harsh to the touch, and that it could be broken easily by using the hands alone. Dipping the line in water increased its tensile strength very much. The fibers of the Italian hemp appeared to be so brittle that the smallest lines made from it are almost worthless. Commenced using "electric primers" with this round.
	22	The same piece of linen line (150 yards of No. 7 line) used in above round was tied as before to a No. 3½ linen. Either one of the lines broke at the knot, or else the knot slipped and came untied. There was nothing in the appearance of the ends of the lines to indicate which had actually occurred. The shot with the large line attached ranged 541⅓ yards, and fell 6 feet to the left of the plane of fire.
	23	Velocity of wind at office (elevated anemometer) 12.81 miles per hour. The shot carried out all the line (linen No. 3½), the end being found 30 yards from the faking-box. There were seven kinks found in the line, two of which were pretty bad ones.
	24	Line (Italian hemp No. 4½) broke; cause, lateral vibrations and brittleness of fibers. Shot carried away 304¼ yards of line. Range of projectile, 807 yards; deviation from plane of fire, 60 feet to the left.
	25	Velocity of wind at office 15.93 miles per hour.

1. *Synoptical transcript of notes from the firing record*—Continued.

GUN C.—CALIBER 2.5 INCHES—Continued.

Date.	No. of round.	
1878.		
May 10	26	Started the dovetailing of faking-box C, near the top, on the side nearest to the gun. This box had one hasp broken in transportation. The brass hinge-pin had been riveted too tightly.
	27	No remarks.
11	28	Italian hemp line No. 7. The line broke squarely off, leaving 27 feet attached to the shot. The violence of the up-and-down vibrations of the line was sufficient to split the bottom of the faking-box. Range of shot, about 1,100 yards.
	29	Broke end of faking-box. Velocity of wind at office, from observations two minutes apart, was 34.6 miles and 36 miles per hour. Five minutes after shot was fired, surface velocity of wind was 25 feet and 31.66 feet per second.
	30 31 32 33	Wind gusty. Direction of wind ("side wind") caused the line to drift badly to one side of the plane of fire. A strong rear or side wind allows the projectile to move more or less sidewise, thus exposing more surface to the action of the air, and, consequently, increasing the resistance of the air and diminishing the range. With a strong head wind, the strain of the line upon the oblong projectile appears to keep the point up and to extend the range somewhat. During one hour the velocity of the wind was taken at equal intervals at the office (anemometer 50 feet above the ground) with the following serial results, viz: 11.54, 19.0, 17.47, 21.18, 26.86, 22.8, 22.0, 19.8, 11.92, 18.7, 24.3, 12.5, 24.6, 22.5, 30.5, 26.4, and 22.5 miles per hour. In round No. 33, Italian hemp line No. 4, "ordinary finish," drifted so far to the left that it fell into the salt water. The exact "drift" could not be measured, but was a little more than 75 yards. The line caught on an old jetty under the water: two men pulling on the wet line could not break it, though each of them took a couple of turns around his arm and placed the line over his shoulder in order to exert more fully his strength. The line was cut in order to recover it. The wet line was very difficult to fake, being stiff and rendered sticky by the loosened starch finish.
22	34	Line emptied from faking-box into tray before fixing. Shot rotated three or four times.
	35	Line emptied into tray as before. Shot rotated about five or six times. Velocity of wind at office 21.9 miles per hour.
	36	Line emptied into tray as before. All of the line carried out except 4 tiers of fakes.
	37	Line emptied into tray as before. All of the line but about 50 yards carried out.
	38	Line emptied into tray as before. All of the line carried out. End of line 10 yards from tray. Line had too much paraffine on it; felt very greasy.
	39	Line emptied into tray as before. All of the line (No. 5) except 9 tiers carried out.
	40	Line emptied into tray as before. All but 7 tiers of the line carried out. Wind gusty during the above experiments for this day. Velocity of wind at office 17 miles per hour, immediately after fortieth round.
	41	Fired out to sea directly against the wind. No drift to the line. About 600 yards of line drawn out of box. Range unknown; lowest estimate given by those present was over 450 yards. Probably did not vary much from that distance. Action of projectile in the trajectory during its flight, excellent. Shot recovered by hauling in line. Recoil of gun and carriage 15 feet.

1. *Synoptical transcript of notes from the firing record*—Continued.

GUN C.—CALIBER 2.5 INCHES—Continued.

Date.	No. of round.	
1878. May 22	42	Fired to sea directly against the wind. The line was in loose coils on the sandy beach. The wet line was hauled in through the water and sand "hand-over-hand" and coiled without any care whatever, in order to ascertain what could be done in a similar case when the circumstances required great haste. This line, with the "water-proof finish," was stiff, but held less sand and was not nearly so sticky as that having the "ordinary finish." It was deposited in three coils near together, and was fired. The first coil, though somewhat kinky, ran out pretty well; part of second coil ran out, when the remainder was caught up by a vibrating loop, forming a bad tangle, through which the cord was drawn tightly until it broke or was cut by the other coils. This large mass of rope, over a foot in diameter, was carried out to sea over 80 yards before the line parted. The recoil of the gun-carriage was about the same as in the previous shot. The action of the gun-carriage upon the sand was unexceptionable; it slided to the rear easily without any tendency to turn over whatever.

CHAPTER III.

VELOCITY AND FORCE OF THE WIND.

In this chapter will be given tables containing the velocities of the wind from one-hundredth of one foot per second to one hundred and fifty feet per second, with their equivalents in miles per hour; also the pressure per square foot in pounds for the different velocities of the wind from one mile to one hundred miles per hour.

The velocities of the wind as recorded by the signal service self-registering anemometer are given for the days upon which experiments were made at Sandy Hook, N. J.

The data for Sandy Hook, N. J., were kindly furnished by the Chief Signal Officer of the Army and by Sergeant P. J. Huneke, United States Signal Service.

I.

Table of velocities of the wind.

VELOCITY OF THE WIND.							
Per second, feet.	Per hour, miles.	Per second, feet.	Per hour, miles.	Per second, feet.	Per hour, miles.	Per second, feet.	Per hour, miles.
.01	.007	1	.68	16	10.91	10	6.82
.02	.014	2	1.36	17	11.59	20	13.64
.03	.021	3	2.05	18	12.27	30	20.45
.04	.027	4	2.73	19	12.95	40	27.27
.05	.034	5	3.41	20	13.64	50	34.09
.10	.068	6	4.09	21	14.32	60	40.91
.20	.136	7	4.77	22	15.00	70	47.73
.3	.205	8	5.45	23	15.68	80	54.54
.4	.273	9	6.14	24	16.36	90	61.36
.5	.341	10	6.82	25	17.05	100	68.18
.6	.409	11	7.50	26	17.73	110	75.00
.7	.477	12	8.18	27	18.41	120	81.82
.8	.545	13	8.86	28	19.09	130	88.63
.9	.614	14	9.55	29	19.77	140	95.45
1.0	.681	15	10.23	30	20.45	150	102.27

II.

Velocity and force of the wind.

Velocity per hour.	Pressure per square foot.	Character of wind.	Velocity per hour.	Pressure per square foot.	Character of wind.
Miles.	*Pounds.*		*Miles.*	*Pounds.*	
1	0.005	Hardly perceptible.	17	1.422	
2	.020	Just perceptible.	18	1.594	
3	.044	Do.	19	1.776	
4	.079	Gently pleasant.	20	1.968	
5	.123		25	3.075	Very brisk.
6	.177	Pleasant.	30	4.429	
7	.241		35	6.027	High wind.
8	.315		40	7.873	
9	.399		45	9.963	Very high wind.
10	.492		50	12.300	A storm or tempest.
11	.595		60	17.715	A great storm or strong gale.
12	.708		70	24.500	Violent gale.
13	.831	Pleasant; brisk breeze.	80	31.490	Hurricane.
14	.964		90	40.500	
15	1.107		100	49.200	Most violent hurricane.
16	1.260				

III.

Statement showing the hourly velocity of the wind at Sandy Hook, New Jersey, on the dates and at the hours below given, compiled from the records on file in the Office of the Chief Signal Officer, U. S. A.

[Elevation of anemometer above ground, 40 feet 7 inches.]

Date.	8.30 a. m. to 9 a. m.	9 a. m. to 10 a. m.	10 a. m. to 11 a. m.	11 a. m. to 12 noon.	11.30 a. m. to 12 noon.	12 noon to 1 p. m.	1 p. m. to 2 p. m.	2 p. m. to 3 p. m.	3 p. m. to 4 p. m.	4 p. m. to 5 p. m.	5 p. m. to 6 p. m.	Total.
	Miles.	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*
May 7, 1878	....	....	....	15	....	17	15	13½	16	19	....	95½
May 8, 1878	....	4½	6	....	....	....	....	....	....	....	....	10½
May 10, 1878	7	15	15	15	....	....	....	....	....	....	....	52
May 11, 1878	....	....	27	11½	....	20½	17	28	29	....	....	133
May 13, 1878	....	....	....	....	8	16	14	14	....	....	....	52
May 14, 1878	2½	4	1⅓	1½	....	½	11½	13	13	13	12	71

WAR DEPARTMENT, OFFICE OF THE CHIEF SIGNAL OFFICER, U. S. A.,
Washington, D. C., May 28, 1878.

OFFICE OF OBSERVATION SIGNAL SERVICE U. S. A.,
Sandy Hook, N. J., May 23, 1878.

LIEUTENANT: I have the honor to submit the requested information in regard to the velocity of wind on stated dates and hours, as far as the records now at this station enable me to do so. I have written to the Chief Signal Office for the missing data [*i. e.* for May 7 to May 14, 1878].

Elevation of anemometer above ground, 40′ 7″.

Date.	Time.	Hourly velocity.					Total number of miles.	Average hourly velocity.
		10 to 11.	11 to 12.	12 to 1.	1 to 2.	2 to 3.		
May 21	10.00 a. m. to 2.00 p. m.	12	10	13	12	....	47	11.75
May 22	10.00 a. m. to 3.00 p. m.	23	19	22	20	15	99	19.80
May 23	10.00 a. m. to 12.00 m.	18	13	....	....	....	31	15.50

Very respectfully, your obedient servant,
P. J. HUNEKE,
Sergeant Signal Service United States Army.

D. A. LYLE,
Lieutenant of Ordnance,
Sandy Hook, N. J.

IV. REMARKS ON THE EFFECT OF A CURRENT UPON THE SHOT-LINE.

After communication has been established between the shore and a stranded vessel by means of the shot-line, another troublesome factor often intrudes itself into the problem. By this is meant the effect upon the line of an inshore current running parallel to the coast and between the shore and vessel, commonly called by surfmen the "set."

There is little doubt that the influence of this current has been usually underrated in those attempts to haul off a whip-line or hawser which have failed. No definite calculations upon the effect of this current can be made at the present time from the lack of the necessary experimental data. This subject has already engaged the attention of the Chief of the Life-Saving Service, and steps have been taken for the purpose of eliciting information upon this important point.

PART IV.

HISTORICAL.

NOTE.

This part of the report is devoted to the history and use of the Manby apparatus, to some others of more recent date, and to the Boxer life-saving rockets.

The Manby apparatus is described in detail in books not generally accessible to those most interested in the results of Captain Manby's experiments.

The same may be said in regard to the Boxer life-saving rocket, which is now generally used in England, and is also used to some extent in this country.

The descriptions transcribed have been accredited to the sources from which they were taken, and have, by preference, been given in the phraseology of their authors.

These extracts exhibit the results of many valuable experiments. It is of the first importance that those charged with the use of such apparatus should be in possession of all the knowledge upon the subject that can be obtained.

The desire of the writer to place these instructive papers within the reach of the keepers of life-saving stations must be his apology for introducing them.

D. A. L.

CHAPTER I.

SECTION I. HISTORY OF MANBY'S LIFE-SAVING APPARATUS.

[Extract from Encyclopædia Britannica, eighth edition, Vol. XIII, pp. 440–445.]

It had occurred to Lieutenant Bell, in 1791, that a rope might be thrown from a ship which had struck, by means of a mortar carrying a heavy shot, and upon the principle of the gun-harpoon; and he showed the practicability of the suggestion by an actual experiment, in which a deep-sea line was carried to a distance of about 400 yards. (Trans. Soc. Arts, XXV, p. 136.) He recommended that every ship should be provided with a mortar capable of carrying such a shot, and observed that it might be placed on a coil of rope to be fired, instead of a carriage. The line was to be coiled on handspikes, which were to be drawn out before the mortar was fired.

In 1792 he received a premium of fifty guineas from the Society of Arts (Transactions, X., p. 204); and he obtained his promotion in the ordnance as an acknowledgment of his merits. The shot was to weigh about 60 pounds or more, and the mortar 5 or 6 cwt. The experiments of the French artillery at Lafere were subsequent to those of Mr. Bell, though they have sometimes been quoted as the first of the kind. * * *

The means to be employed by persons on shore, in cases of shipwreck, depend either on projecting a line over the ship or on the use of a life-

boat. Mr. Bell had cursorily observed that a line might be carried over a ship from the shore by means of his mortar; but for the actual execution of this proposal, in a variety of cases, we are indebted to the meritorious exertions of Capt. G. W. Manby, whose apparatus, according to the report of a committee of the House of Commons, dated in March, 1810, appears "to be admirably adapted to its purpose, and to have been attended with the fullest success in almost every instance." In consequence of this report, Captain Manby was thought worthy of a Parliamentary reward; and he afterwards published a description of his inventions, under the title of "An Essay on the Preservation of Shipwrecked Persons. 8vo. London, 1812." He had previously received a gold medal from the Society of Arts in 1808 (Transactions, XXVI, p. 209). His success makes it expedient to extract from his essay a detailed description of the apparatus, and it will be easy to make it somewhat more intelligible by a slight alteration of the order of arrangement:

The method of affixing a rope to a shot for the purpose of effecting communication, when projected from a piece of ordnance, over a stranded vessel, was at length succeeded in by introducing a jagged piece of iron, with an eye at the top, into a shell, and securing it by filling the hollow sphere with boiling lead; and in another way, by drilling a hole through a solid ball, and passing a piece of iron, with an eye to it, as before described, to the bottom, where it should be well secured by riveting.

To produce the means of connecting a rope to a shot, and prevent its being burnt, and rendering it "irresistible" to the powerful inflammation of gunpowder, was the labor of infinite time, and the number of experiments to accomplish it is beyond all possible conception. Chains in every variety of form and great strength breaking, proved that it required not only an elastic but a closer connected body. At length some stout platted hide (Fig. 5, Plate XLVII), woven extremely close to the eye of the shot, about 2 feet in length beyond the muzzle of the piece, and with a loop at the end to receive the rope, happily effected it.

This method is certainly desirable, as the rope may, immediately [as] it is required, be affixed to the loop, and applied in service. The form of the platted hide may likewise be woven by twisting it in the manner that the lashes of whips or ropes are spun. There is another method, by passing a rope through a case of leather, taking the greatest care that it is so well secured at the eye of the shot as to leave no room for the *slightest play*, as is represented by the annexed *barbed shot*.* (Fig. 6, Plate XLVII.)

When the crews of the distressed vessel are incapable of availing themselves of the benefits arising from communication, they having previously lashed themselves in the rigging to prevent being swept away by the sea, which is repeatedly breaking over them, and when, from long fatigue and the severity of the storm (on which occasion it too frequently occurs), they totally lose the use of their limbs and are rendered incapable of assisting themselves in the slightest degree, the advantages of this shot are, that, on its being projected over the vessel and the people of the shore hauling it in, it firmly secures itself on some part of the wreck or rigging, by which a boat can be hauled to the relief of the distressed objects, and by the counterbarbs it is rendered impossible [that it should] give up its hold, or slip, while that part of the wreck remains to which it has secured itself.

Among the many that have been saved by this shot, the following are testimonials of a few of the cases:

"We, the crew of the brig Nancy, of Sunderland, do hereby certify that we were on board of the said vessel when she was stranded on the beach of Yarmouth, on Friday morning, the 15th of December, 1809, and compelled to secure ourselves in the rigging to prevent being swept away, the sea running so high on the vessel. And we do further declare and certify that Captain Manby, firing a rope with a hooked shot, securely holding on the wreck, enabled a boat to be hauled from the shore over the surf to our relief, otherwise we must inevitably have perished."

This certificate is attested by six signatures.

Facilitating communication is at all times of importance; but when the stranded vessel is in momentary danger of going to pieces, this point becomes a consideration of extreme urgency. I feel a persuasion that this particular service can only be carried into effect by a small and light piece of ordnance, the range of which is conse-

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*The writer can find no record of the adoption by any government or society of Manby's barbed shot, or of any other anchor shot. Thus far the use of this class of projectiles seems to have been limited. Many practical difficulties in regard to their efficient use yet remain to be overcome.—D. A. L.

quently very inconsiderable, when compared with that of a large and heavier piece, as it is weight alone that conveys the rope. In order, therefore, to increase the powers of a shot projected from a small mortar, its natural form must be varied so as to give it additional "preponderance." The annexed shape, in the form of a pear (Fig. 3), has been used with the greatest success; for, by the increased weight, the shot's momentum and power over the line is in consequence considerably augmented in its range; and when made to fit the piece as close as possible, a great increase of velocity is likewise produced from that decrease of windage.

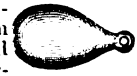

Fig. 3.

Portability in the construction of a piece of ordnance (as just described) is the very essence of this service; and communication with the stranded vessel or wreck may be effected with a cord, by which cord a rope can be conveyed, and by that rope a hawser or cable sent to the distressed vessel; for this purpose the annexed was constructed. (Fig. 7, Plate XLVII.)

A person completely equipped with every necessary apparatus to effect communication with a vessel driven on a lee shore, * * * the horseman, fully equipped, traveled a mile and a half, the howitzer was dismounted, and the line projected 153 yards, in six minutes.

The application of a small piece of ordnance likewise offers particular advantages, capable of being employed from a boat to go to the assistance of a vessel grounded on a bar when running for a harbour, the necessity of which repeatedly occurs, and was twice witnessed at Blakeney on the 10th of November, 1810, when boats endeavoured to go to their relief, and were enabled to get out of the harbour on the ebb tide, within 20 yards of the vessel; but it was found impossible to approach them nearer. Had such boats been provided with a piece of this description, and the same firmly secured on a stout piece of plank, by the holes left at each corner of the iron bed, they might have projected a small rope, coiled in a crate or basket made to the form of the bow of the boat; and the persons in the boat so provided would not have remained the distressed spectators of the untimely end of their fellow-creatures without being able to afford them the smallest relief, although so little was then wanted for that desirable purpose.

Although advantages have been pointed out in the use of these small mortars, it is necessary to be kept in remembrance that they are produced for particular services, as the nature of the coast and circumstances attending the distressed vessel will direct what piece is best adapted to the undertaking.

To enable the mind to form a judgment of what can be effected by other pieces, the following are the minutes of experiments made with a 5½-inch brass mortar, stating the quantity of powder used, and distance the ropes were projected against a strong wind, at the angle of 17° (elevation), weight of the mortar and bed about 300 pounds:

Ounces of powder.	Yards of 1¼-inch rope.	Yards of deep-sea line.
4	134	148
6	159	182
8	184	215
10	207	249
12	235	290
14	250	310

With a short 8-inch mortar, the weight of which and bed was supposed to be about 700 pounds, the angles of elevation uncertain:

Ounces of powder.	Yards of deep-sea line.	Yards of 2-inch patent Sunderland rope, capable of hauling the largest boat from a beach.
32	439	....
32	479	....
32	....	336

Directions for using the apparatus.—When the rope (which should be pliant and well stretched) is brought on the beach or cliff opposite to the stranded vessel, the most even spot, and free from projecting stones, should be selected to lay it on, and great care be taken that no two parts of it whatever overlay or even touch each other, nor must it be laid in longer lengths than of two yards. But to project a small line or cord, it will be necessary, if it is required, to contract the faker to half a yard at most, to avoid the jerk received at the end of each right line. The best method, with such a description of cord, is to lay it on the ground in the most short and irregular windings

to relieve it from this powerful impulse. To prove the effect of the impulse on a rope, if it is faked in lengths of 10 or 15 yards, it will break each time, as it then becomes a most powerful pendulum. These precautions are absolutely necessary to the success of the service.

The following has, after various trials, been found a certain method of laying the rope, and placing it into compartments. (*French Faking*, Fig. 1, Plate XLVIII.)

A particular attention to this mode will never fail with a good rope, when the impediments are removed that might otherwise obstruct its rapid flight. Its advantages are, that it will allow the eye rapidly (yet correctly, *just before firing*, which is absolutely necessary) to pass over the different compartments, and at once discover if any fake has been displaced by the storm, or by any other casualty or accident come in contact with another part, which would destroy its application by the rope breaking.

It may likewise be coiled in the manner used in the whale-fishery, *whale lair* (Fig. 2, Plate XLVIII); and in the method called *chain faking* (Fig. 3, Plate XLVIII.) It is, however, necessary to add that great attention is required in laying it agreeably to the two latter methods, arising not only from the arm being liable to get under certain parts of the rope, and thereby displace it, but from the great anxiety of mind natural on these occasions, where the lives of fellow-creatures are literally dependent on the correctness with which the rope is laid. It is therefore extremely difficult, in a moment of agitation, to determine whether any overlay has taken place, an error that would infallibly destroy every endeavour, and occasion even the fate of those whose lives we might be exerting ourselves to preserve. Could persons in the performance of this service be always collected, the two latter methods would have a decided advantage over the first mode of faking, they being laid in a much less space of time. As all these methods of laying the rope occupy time to place it with the care necessary, and as it has repeatedly happened that vessels, very soon after grounding, have gone to pieces, and all hands perished, it was necessary to produce a method of arranging the rope so that it could be immediately projected as soon as it arrived at the spot; and none proved so effectual as when brought ready in a basket (Fig. 4, Plate XLVIII).

In this case, the rope should be most carefully laid in alternate tiers or fakes, no part of it overlaying, and it should be well secured down, that in traveling it be not displaced; but, above all, no mistake must happen in *placing the basket properly*. For example, that the end of the basket, from which the shot hangs in the above figure, should be previously marked, and must be placed toward the sea or wreck, that the rope be delivered freely, and without any chance of entanglement. It will be scarcely necessary to add, there will be several tiers of the rope when laid. The utmost care and attention are required in laying the rope in tiers with strict regularity, to prevent entanglement. The next is the application of the mortar. If the wind is sideways to the shore, it must be pointed sufficiently to windward to allow for the slack of the rope lighting on the object, as the rope will, of course, be considerably borne to leeward by the effects of a strong wind, and by its being laid at a low elevation insures the rope falling against the weathermost part of the rigging. While this service is performing, great care should be taken to keep the mortar dry; nor should it be loaded until everything is ready. When that is done, it should be primed; but as it would be impossible to do it with loose powder in a storm, a tube is constructed in the simplest manner of common writing paper (the outer edge being cemented with a little gum) in this form (Fig. 5, Plate XLVIII). It is filled with meal gunpowder, made into paste with spirit of wine; when in a state of drying, run a needle through the center, and take care the hole is left open, for, on the tube being inflamed, a stream of fire darts through the aperture with such force as to perforate the cartridge. The mortar should then instantly be fired; and in order to lessen a difficulty that has often occurred in performing this service, a pistol may be used, having a tin box over the lock, to exclude the effect of wind or rain on the priming; and the muzzle being cut [obliquely], dilates the inflammation, so as to require but little exactness in the direction of the aim.

We will suppose the communication to be secured, although it is scarcely necessary to offer any other assistance than that of a rope, as the inventive genius of a sailor will supply everything else; yet I could expect the people on shore to get a boat ready for meeting the vessel when driven on a beach. It is the promptest and most certain method of relief as well as the most easy to be accomplished; for by hauling her off with the rope projected, the boat's head is kept to the waves, and not only insures safety by rising to the surge, but prevents her upsetting.

When the rope attached to the shot (not having barbs to it) is fired over the vessel and lodges, let it be secured by those on board, and made fast to some firm part of the rigging or wreck, that they may haul off a boat by it; but should there not be any boat, then haul on board by the projected rope a larger one, and a tailed block, through which a smaller rope is rove. Let the large rope be made fast at the masthead, between the cap and the top of one of the lower masts, and the tailed block a little distance below it; but, if the masts should have been cut or carried away, then it must be made fast to the loftiest remaining part of the wreck. When this is done.

there will be supplied from the shore a cot, hammock, netting, basket, hoop, or any of the numerous resources of seamen, which will run on the larger rope, and be worked by the people on shore. If a cot be used, the men may be so securely fastened to it as to preclude all possibility of falling out, and then be brought from the wreck, one by one, in perfect safety.

While communication is gaining, three stakes should be driven into the ground in a triangular position, so as to meet close at the heads to support each other. As soon as communication has been effected by the crew of the vessel and they have secured the line attached to the shot made fast to these stakes, the crew will haul on board by it a large rope and a tailed block, through which a smaller rope is to be rove, both ends of which (the smaller rope) are to be kept on shore. When they have secured these on board and the larger rope is rove through the rollers, let a gun-tackle purchase be lashed to it, then lash the purchase to the stakes. By the means of the purchase the larger rope may be kept at a fit degree of tension; for, if care be taken to slacken the purchase as the ship rolls out to sea, the danger of the rope being broken will be guarded against; and, on the other hand, if the purchase be gathered in as the ship rolls toward the shore, the slackness of the rope, which would prevent the cot traversing as it ought to do and plunge it in the water more than it otherwise would, will be avoided.

Supposing neither boat nor cot apparatus at hand, first cast off the shot from the projected rope, and with a close hitch let it be put over the head and shoulders of the person to be saved, bringing it close under each arm, drawing it tight, *observing particularly the knot is on the breastbone;* for, by having the knot in that position, on the people of the shore hauling the person from the wreck, he will naturally be on his back, consequently the face will be uppermost to sieze every moment for respiration after each surf has passed over the body.

If circumstances compel recourse to this method, care must be taken to free the rope from any part of the wreck and to jump clear away; but should there be more than one on board each man should make himself fast in the same way about four feet from the other and join hands, all attending to the same directions.

For giving relief to vessels stranded on a lee shore in a dark and tempestuous night.—It will be requisite, first, to devise the means of discovering precisely where the distressed vessel lies when the crew are not able to make their situation known by luminous signals; secondly, to produce a method of laying the mortar for the object with as much accuracy as in the light; thirdly, to render the flight of the rope perfectly distinguishable to those who project it and to the crew on board of the vessel, so that they cannot fail of seeing on what part of the rigging it lodges, and consequently have no difficulty in securing it.

To attain the first object a hollow ball was made to the size of the piece, composed of layers of pasted cartridge paper of the thickness of half an inch, having a lid on the top to contain a fuse (Fig. 6, Plate XLVIII), and it was then filled with about fifty luminous balls of star composition and a sufficient quantity of gunpowder to burst the ball and inflame the stars. The fuse fixed in the ball was graduated to set fire to the bursting powder at the height of 300 yards. Through the head of the fuse were drilled holes at equal [distances], to pass through them strands of quick-match to prevent the possibility of any accident from the match falling out or from its not firing the fuse. On the stars being released they continue their splendor while falling for near one minute, which allows ample time to discover the situation of the distressed vessel. During the period of the light a stand with two upright sticks (Fig. 7, Plate XLVIII), painted white to render them more discernible in the dark, was ready at hand and pointed in a direct line to the vessel.

A shell affixed to the rope, having four holes in it to receive a like number of fuses (headed as before described), and filled with the fiercest and most glaring composition, which, when inflamed at the discharge of the piece, displayed so splendid an illumination of the rope that its flight could not be mistaken.

To get a boat from a beach over the surf.—The importance of going to the relief of ships in distress at a distance from the land, or for taking off pilots, was viewed as of the highest consequence by the elder brethren of the Trinity House, and offered to my particular attention by several distinguished characters. After numerous experiments to accomplish it in various ways, the mode following was most approved: About forty fathoms of 2½-inch rope, made fast to two moving anchors, was laid out parallel with the shore, at a distance beyond the sweep of the surf; to the center of this rope was made fast a buoy, of sufficient power to suspend the great rope and prevent it from chafing on the sand, rock, or stones, as well as embedding, a circumstance that has rendered it impossible on a sandy or shingly coast to heave out an anchor with a rope to it from the shore. As this service should be performed in fair weather (to be prepared for the storm), it may be regulated with the greatest exactness, and should take place at the top of high water, that the upper part of the buoy may be at the full stretch of its power, and only seen at that time. Should the shore be extremely flat, it will be

desirable to place another set at a sufficient distance beyond the first to insure the operation of this method in any state of the tide.

The royal mortar being brought to the spot, is to be pointed in the direction for the buoy, and should be laid at a very low elevation, but such as to insure the range: for the more it is depressed the less slack of rope there will be from the parabola formed in the shot's flight; the basket with the rope ready laid (having a barbed shot to it) is to be placed in the front of the mortar; on its being fixed, instantly haul the slack of the rope in, to prevent the effect produced on it by a strong tide; which being done, let the remainder be gently hauled in to insure the shot's grappling with the great rope; when that is caught and hooked, a power will be acquired fully adequate to the service.

As a cast-iron anchor appears particularly adapted to this method, and would be much cheaper than hammered, Fig. 8, Plate XLVIII, is a plan of one which the honorable the navy board approved, and allowed me to cast at their expense for the purpose of making the experiment.

When a vessel is in that extreme and perilous situation, driven under a rugged and inaccessible cliff, and in danger of going soon to pieces, the most prompt method I should suggest is by lowering to the crew a rope with stiff loops spliced into it (Fig. 9, Plate LXVIII), at the distance of a foot and a half from each loop, of sufficient size to contain the foot, by which they can ascend as a ladder.

This rope ladder is capable of being projected, and one of an inch and a half rope was thrown from a mortar 194 yards. It might also, from the simplicity of its structure, be extremely useful in escaping from a house on fire. By making one end fast to the leg of a bed or a table, the person would come down from the window in safety, and with much less difficulty and quicker than with the common rope ladder, which is heavier and more unwieldy. It has great advantages when employed in saving shipwrecked men in situations just described, when, from extreme cold and almost benumbed limbs, it would be impossible for them to climb up a rock or ascend it even by the aid of a common rope. The holds thus spliced in will support both hands and feet.

The report of the committee of the House of Commons contains also a paper of instructions for the managers of Captain Manby's apparatus on shore, which are somewhat more minute than the directions published in his essay. For example:

If the wind be sideways to the shore the mortar must be pointed sufficiently to windward to allow for the slack of the rope lighting on the object, as the rope will of course be borne considerably to leeward by the effect of a strong wind.

The distance your judgment decides the vessel to be from the shore should regulate the charge of powder as stated in the scale, taking just a sufficient quantity to clear the object. An attention to this will be more certain of your effecting communication and guarding against the danger of the rope breaking or any other circumstance that might prevent the successful performance of the service. The elevation of 15° is to be preferred, particularly if the wind is sideways, pointing the mortar sufficiently to windward, as the rope would then fall against the weathermost part of the rigging of the stranded vessel.

When a vessel is driven on shore in the night you will flash gunpowder as often as convenient on your way. This will animate the crew and denote to them you are coming to their assistance. On getting to the spot where you have reason to suspect the vessel lies, as you are not able to discover her, from the extreme darkness, and if the people on board cannot [make known] their situation by luminous signals, or noises (which they will be directed to make if possible), you will lay the mortar at a very high elevation and fire a light ball.

Just before you fire (the rope) it would be advisable to let off a blue light to put the crew on their guard, to look out, and be ready to secure the rope. The service can be performed with a carronade.

In Chapter IV we have a copy of directions to persons on board vessels stranded on a lee shore, proposed to be delivered to the masters at the custom-house. It is observed that even snapping a pistol, when the powder is wet, may sometimes afford a signal visible on shore, from the sparks of the steel alone. The other parts of the directions will be supplied by those who understand the principles of the proposed mode of relief.

Rockets have of late years been much employed instead of the mortar, in Manby's apparatus for throwing a line to a ship in distress. "Dennett's Rocket Apparatus" is supplied to many stations along the coast. The only advantage the rocket has over the mortar is its greater portability;

for, being much lighter, it can be used with greater facility among rocky cliffs, and in positions difficult of access. The disadvantges of rockets are, that they are somewhat uncertain, sometimes exploding as soon as ignited, to the danger of the by-standers; and they are also liable to deteriorate from the effects of damp or of age. Moreover, being expensive, they cannot be often employed in trials, so as to keep up the practice of the people employed in using them. The range of a shot from a 24-pound mortar, which is the ordinary size, is about the same as that of a 12-pound rocket, which is the largest in use. As the management of the mortar and rocket apparatus is much better understood by the officers and men of the coast-guard service than by ordinary boatmen and fishermen, it has been almost entirely left in their hands, and is provided by the board of customs.

Several inventions, or variations, in the Manby apparatus may be just glanced at. M. G. Delvigne uses a howitzer instead of a mortar, while a portion of the line to be carried is contained in the projectile. Mr. Greener has a method of discharging a rocket, with a line attached, from a light harpoon-gun. When discharged, the rocket ignites, and is said to prolong the range to a greater distance than if the gun or rocket were alone employed.

Captain Jerningham, R. N., has an anchor of a particular form, which he proposes to fire from a Manby mortar, in sufficient numbers to afford the means of hauling a life-boat through the surf.

Mr. A. G. Carte employs a war-rocket instead of a Dennett rocket.

SECTION II.—MANBY'S SHOT.

[Extract from "Ammunition," by Captain Majendie, R. A., published in London in 1867.]

1. *History.*

The plan of saving lives in cases of shipwrecks by means of a line thrown so as to establish a communication between the ship and the shore seems to have been first proposed about the close of the last century, by Lieutenant Bell, Royal Artillery.[1] This officer proposed to project from a mortar a spherical shell filled with lead, and having "a deep-sea line" attached. Some trials were made with the apparatus in 1791,[2] before a committee of the Society for the Encouragement of Arts, Manufactures, and Commerce, and the success of the experiment was so marked and unequivocal,[3] that in the following year the society adjudged the inventor a reward of fifty guineas.[4]

Lieutenant Bell's claim to the priority of the invention was also recognized by a committee of artillery officers assembled at Woolwich in May, 1811, to report on "Captain Manby's invention for saving the lives of shipwrecked mariners," this committee reporting that they feel that—

They should not entirely discharge their duty were they to omit observing that the committee of the honorable House of Commons do not seem to have been informed of all the means proposed by the late Lieutenant Bell, of the Royal Artillery, for the

[1] It appears from Kane's List that Lieutenant Bell was promoted from sergeant to a lieutenancy in the invalid battalion.—(Kane's List of the Royal Regiment of Artillery, p. 21.)

[2] August 29, 1791.—(Repertory of Arts for 1808, vol. xiii, p. 315.)

[3] The line was thrown to a distance of 400 yards.—(*Ibid.*, 315.)

[4] A full account of the experiments and drawings, and a description of the apparatus are given under the head of "Account of a method of throwing a rope on shore by means of a shell from a mortar on board a vessel in distress." By Lieut. John Bell, Royal Artillery, in the Repertory of Arts, 1808.

attainment of the same laudable object; it being stated in that honorable committee's report, that "Mr. Bell's invention is totally inapplicable in all cases of vessels being stranded," and that Captain Manby's invention is new.[5]

In justice, therefore, to the memory of Lieutenant Bell, and to his surviving family, and with respectful deference due to the judgment of the honorable committee, the concluding of the seven observations inserted in one of the papers of Lieutenant Bell's account to the Society for the Encouragement of Arts, Manufactures, and Commerce, is subjoined in his own words, as published in that society's Transactions, and in the Repertory of Arts for 1808, p. 318, by which observations it appears *that Lieutenant Bell then proposed what Captain Manby has since so ably and so successfully carried into effect.*[6]

The passage "in Lieutenant Bell's own words," referred to by the committee, is as follows:

There is every reason to conclude that this contrivance would be very useful at all ports of difficult access both at home and abroad where ships are liable to strike ground before they enter the harbor as Shields Bar, and other similar situations, when a line might be thrown over the ship, which might probably be the means of saving both lives and property; and, moreover, if a ship was driven ashore near such a place, the apparatus might easily be removed to afford assistance, and the whole performance is so exceedingly simple that any person seeing it done would not want any further instruction.[7]

It is thus placed beyond doubt that Lieutenant Bell's proposition was not limited to throwing a rope from a vessel to the shore, but included the reverse operation of throwing a rope from the shore to the assistance of a stranded vessel, and this by almost exactly the same means as were subsequently successfully applied by Capt. G. W. Manby, R. N.

But if the merit of having been the first to propose this plan cannot, in justice, be conceded to Captain Manby, it is at least indisputable that that officer was the first practically to apply it, and that by his exertions the details were matured and the idea successfully carried into effect;[8] for, in spite of the success which had attended Lieutenant Bell's experiments, his proposition does not appear ever to have received official recognition, or to have been practically entertained or adopted.[9]

Captain Manby worked out the subject with great care and ingenuity, and in 1811 his plan was experimented upon by the committee of artillery officers before alluded to.[10]

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[5] This allusion to the opinion of the "committee of the honorable House of Commons" has reference to a report made by a committee of that house in 1810, in which Lieutenant Bell's claim to any merit attaching to priority of invention is ignored, and his proposition spoken of in the words quoted in the text, viz, as "totally inapplicable in all cases of vessels being stranded," while Captain Manby's proposition is treated as original. The incorrectness of this opinion is sufficiently shown by the passage from the report above quoted and by Lieutenant Bell's own remarks, which I have given farther on.

[6] The Annual Register for the year 1811, p. 521.

[7] Repertory of Arts for 1808, vol. xiii, p. 318.

[8] "Lieutenant Bell then proposed what Captain Manby has since so ably and successfully carried into effect."—(Report of Artillery Committee, Annual Register for 1811, p. 521.) (See, also, extract from Ency. Brit., xiii, &c., on a preceding page, beginning as follows: "Mr. Bell has cursorily observed that a line" *et seq.*—D. A. L.)

[9] It is not impossible that this arose from the fact that the inventor died shortly afterwards, in 1798.—(See Kane's List of Officers of the Royal Regiment of Artillery, p. 21.)

[10] This committee was composed of the following field-officers of artillery: Lieutenant-General Lloyd, Major-General Ramsay, Colonel Borthwick, Lieutenant-Colonel Rion, Lieutenant-Colonel Spicer, Lieutenant-Colonel Colebrooke, Lieutenant-Colonel Beerer, Major Gold, Major Buckner. Their report bears date, Royal Arsenal, Woolwich, 22d May, 1811, and is entitled "Report from the committee of field-officers of artillery, containing an account of the experiments made at Woolwich on the 18th and 20th May last, on Captain Manby's invention for saving the lives of shipwrecked mariners." Printed by order of the House of Commons.—(Annual Register for 1811, pp. 518 to 521.)

The results of these experiments were in the highest degree successful, and the adoption of his propositions was recommended.[11]

This recommendation led to an address being moved in the House on the 14th June, 1811, to the Prince Regent, "praying that he would be graciously pleased to order that Captain Manby's invention should be stationed on different parts of the coast, &c., and assuring him that the House would make good the expense."[12]

The propositions which Captain Manby had submitted to the committee were eight in number, from which the following are selected as being the only ones having a direct bearing upon the history of the present service life-preserving apparatus. A small brass howitzer, 3-pounder bore, which, with its carriage, weighed 62 pounds, and was strapped on to the fore part of the saddle of a mounted man, 200 yards of log-line being coiled upon a deal frame and slung as a knapsack on the back of the horseman, the line being projected from the howitzer by means of a "*kind of pear shot, 1½ diameters in length,*" and weighing 4 pounds 12 ounces 12 drachms. By means of this shot, and with a charge of 2½ ounces of powder, the howitzer threw the line 143 yards. "Next, a method of affording certain relief to vessels stranded in the darkest night, with an improved mode of rendering the life-rope more distinguishable." This arrangement consisted, firstly in firing what Captain Manby called "light balls," viz, paper shells filled with "stars," from a mortar, to throw a light over the scene; and, secondly, in projecting from the *5½-inch mortar*, charged with 8 ounces of powder, a deep-sea line attached *to a shell with four fuses in it.*[13]

He also suggested at this time connecting the rope to the shot by means of "*some stout strips of hide plaited extremely close at the eye.*"[14]

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[11] The committee were of "opinion that they cannot too strongly recommend an invention, the partial application of which has been attended with such beneficial effects. * * * It is also the wish of the committee to render their full tribute of praise to Captain Manby for his ingenuity in so much improving and bringing into practical use this invention, to the perfecting of which he has so zealously and skillfully devoted himself.—(Annual Register for 1811, p. 520.)

[12] The address was moved by Mr. Wilberforce.—(Annual Register for 1811, p. 521.)

[13] Captain Manby's other propositions and experiments, briefly described, were as follows: An arrangement for firing, "by chemical agency, of two substances, which ignite from coming into contact with one another"; a plan for laying and firing from a boat "when the sea is continually breaking over it"; an arrangement by which the rope is coiled in a basket and then carried to the spot required; a rope-ladder "intended to be projected or conveyed to a crew wrecked under a cliff," consisting of a single rope with loops spliced to it at convenient distances for the support of the feet and hands when climbing; "the distance a deep-sea line can be projected from the shortest 8-inch mortar" (in the course of this experiment a deep-sea line, with 68-pounder shot attached, was projected 439 yards; charge, 2 pounds; elevation, 23°); the distance an 8-inch barbed shot, "with a patent Sunderland 2-inch rope attached," could be projected (the distance was 336 yards).

These propositions will be found *in extenso*, as I have already intimated, in the Annual Register for 1811, pp. 518 to 521. Much interesting information will also be found on the subject of Captain Manby's original propositions in the Encyclopædia Britannica, vol. xiii, pp. 441 to 444, where copious extracts are given from an essay published by Captain Manby himself in 1812, entitled "An Essay on the Preservation of Shipwrecked Persons."

[14] Captain Manby's own words respecting this part of the subject are as follows: "To connect the rope to the shot and prevent it from being burned by the powerful inflammation at the discharge of the mortar was most essentially necessary, and success resulted from almost innumerable experiments; chains in every variety of form and size broke, and proved that not only strength, flexibility, and elasticity, but a body at once continuous and entire, was required. At length some stout strips of hide, plaited extremely close at the eye, happily effected the object so indispensably wanted." (Observations, with Directions on the Method brought into use by G. W. Manby.) See also Encyclopædia Britannica, vol. xiii, pp. 441 to 444, where nearly the whole "observations" (extracted, from Captain Manby's published essay) are given with illustrations.

It is, therefore, placed beyond doubt that Captain Manby's original propositions included, among other contrivances, 1st. A pear-shaped or oblong shot; 2d. A shell of 5½-inch caliber; 3d. A shell containing four fuses; 4th. A plaited hide thong for the purpose of connecting the line to the projectile.

The immediate connection of these details, with the history and origin of the present service pattern, Manby's shot, will at once be perceived, the projectile now used being of an oblong form, 5½-inch caliber, containing four fuses, and having a plaited hide thong. There is no record of the exact form in which Captain Manby's original propositions were adopted, but it would seem, from the "Observations," &c., printed respecting his inventions, as if the majority of them were approved and introduced. It is certain, however, that many were allowed to lapse and become practically obsolete; and it appears that the two projectiles most used were a spherical 24-pounder shot, or shell filled with lead, having an eye-bolt riveted to it, furnished with a stout twisted hide thong, for the purpose of attaching the rope, and a grapnel or oblong shot, with a barbed iron staple, to which the rope was fastened, projecting from one end.

Some demand for this class of stores in 1857-'58 led to experiments being instituted by Colonel Boxer, Superintendent of the Royal Laboratories, the result of which was the introduction and issue, in 1859 or 1860 [15], of an improved and modified Manby's shot, and the pattern then introduced is, with the exception of some slight alterations, which were subsequently (in 1863 [16]) made in the thong, the present service pattern.

Spherical Manby's shot are not, however, altogether obsolete, a pattern of a 6-pounder having been deposited in the model-room of the Royal Laboratory in 1862,[17] to govern the supply on special demand.

Without entering upon a detailed description of the different plans proposed, from time to time, for establishing communication between a stranded vessel and the shore, it will, perhaps, be well to mention that Manby's apparatus is not the only one which has been used for this purpose. The following passage from the Encyclopædia Britanncia will sufficiently indicate the variety and scope of these inventions. * * * [Here follows an extract from the Encyclopædia Britannica, already quoted in these pages.—D. A. L.] * * * Kites have also been suggested as a simple means of carrying a line from[18] a wreck to the shore,[19] and are manufactured for this purpose by the "Shipwrecked Mariners' Society, London Bridge."

The board of trade employed, to a great extent, until 1865, Dennett's rockets, in preference to Manby's shot; and there can be no question that the balance of advantages inclines strongly to the side of the rockets.[20]

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[15] I cannot discover the precise date when these shot were introduced, but it appears that the first issue of them were made in May, 1860, for the use of the coast guard at Lowestoft; and this marks their first *practical* introduction. The proportions of these shot, and of the different stores, fuses, lines, &c., which together constitute a complete "Manby's apparatus," were not officially determined or laid down until the 25th of August, 1862. (See War Office Circular 793, par. 633.)

[16] 12th October, 1863.

[17] 13th January, 1862.

[18] Evidently they are not generally available for carrying a line in the other direction, as the wind will almost invariably be blowing toward the shore.

[19] The Times, 10th of December, 1864, contains two letters on the subject.

[20] Rockets are more portable, as also is the apparatus from which they are fired: they carry their own illuminating agent, and are thus independent of fuses, do not require so long a line as a shot fired from a mortar, where the angle of elevation is greater; and finally, are more accurate, owing principally to the fact that the deflection caused by the action of the wind upon the line is in a great measure corrected by the rocket having a tendency to fly up in the wind's eye.

In 1862 (3d December), the ordnance select committee experimented with some

In 1865 a rocket proposed by Colonel Boxer, R. A., was adopted by the board of trade to supersede Dennett's rocket, to which it is preferred because, "1st. The range of Colonel Boxer's rocket is little, if at all, inferior, and in every other respect it is much superior; 2d. The combination of Mr. Dennett's two rockets is very objectionable, and from their velocity they frequently carry away the line, and sometimes both do not ignite. They are also double the expense."[21]

These rockets are fast superseding Manby's shot at all stations, and the latter may shortly be expected to become entirely obsolete.

There are two natures of Manby's shot in the service, the 24-pounder oblong (Pl. XXXVIII, Fig. 1), or "cylindrical," and the 6-pounder spherical shot. They are designated 24-pounder and 6-pounder, respectively, from their calibers, not from their weights.[22]

The 24-pounder oblong, or "cylindrical" Manby's shot, is a cast-iron cylindro-conoidal projectile,[23] with a slightly rounded base,[24] and about 1¼ calibers in length.[25]

The shot is drilled down its longer axis for the reception of a wrought-iron bolt, which passes completely through the projectile from end to end,[26] and projects about five inches beyond the base, terminating in an eye, to which is attached a plaited hide thong 2 feet in length. Four holes (Plate XXXVIII, Figs. 1, 2), for the reception of "fuses,"[27] are drilled into the shot at the base, equidistant from one another and from the center of the base, and slightly inclining inwards.[28] These holes are

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Manby's and Delvigne's shot against Dennett's 9-pounder rockets, and "the result was a general conviction on the mind of everybody present, and shared by Mr. Delvigne, of the great superiority of the rockets over either of the other plans."

The rockets were fired singly and in couples, at an angle of from 30° to 35°.

"The single rockets carried a line 240 yards, the double rockets 370 yards, with great steadiness of flight, and with less length and weight of line in proportion carried out than the pieces fired at 45°.

"The range obtained with Manby's apparatus, charge 12 ounces, was 200 yards; and with the same mortar firing Mr. Delvigne's elongated shot was 185 yards. The same shot, however, fired from the rifled 5½-inch howitzer at 28°, with 10 ounces, attained a range of 298 yards, but the line broke three times."—(Extract from Reports and Proceedings of Ordnance Select Committee, vol. i, p. 199.)

On the subject of the employment of rockets for carrying a line, see a work published at St. Petersburg, entitled "Application des Fusées au jet des Amarres Sauvetage, par Général-Major Konstantinoff," which contains a good deal of information upon this subject, and explains the construction of a rocket proposed by the author for this purpose, very similar to the Boxer life-saving rocket.

[21] Report of Captain Robertson to the board of trade. The construction of this rocket and of the apparatus which is issued with it will be described in the section on rockets in a succeeding volume of this work.

[22] For weights, see farther on.

[23] Perhaps more strictly an obtuse cylindro-ogival.

[24] It is difficult to say whether this end should properly be called the "base," or the "upper end." When the projectile is placed in the piece, this end is toward the muzzle, and is therefore, strictly speaking, the "upper end," but the shot changes its position on leaving the piece, and what was the front of the shot in the gun becomes the base or hinder part during its passage through the air. Therefore, and as the term is a more convenient one to use, I have designated this end the "base" of the projectile. I have also hesitated between the terms "slightly rounded" and "nearly flattened" in describing the form of the base, but have selected the former as conveying, perhaps, a rather more correct impression of the actual shape.

[25] For actual dimensions, see Plate XXXVIII.

[26] A reference to the drawing of the section (see Plate XXXVIII, Fig. 2), will show the manner in which the bolt is secured to the shot, viz, by means of a projecting head or shoulder on the bolt, which is pushed into the shot from the base up to this shoulder, so much of the bolt as projects at the top of the shot being hammered down to form the head, and thus securely riveting the bolt into its position.

[27] More properly lights (*vide infra*).

[28] The inclination given is just sufficient to throw the flame of the burning "fuses" free of the hide thong.

conical in form, and are about the same diameter as the fuse-holes of the 13 and 10 inch mortar shells.[29] They are about $3\frac{1}{2}$ inches in length and are roughed in the interior to afford a better hold to the fuses.[30]

The hide thong, or "strop," which is fastened to the eye-bolt, is made of four strips of raw horse-hide,[31] doubled through the eye and tightly plaited, the plait being further secured by being stitched in several places with hide.[32]

The end of the thong is formed into a loop which is tightly woolded with fine tarred spun-yarn.[33]

The shot and bolt are painted black before issue; the thong is unpainted. These projectiles weigh (with thong) about $30\frac{1}{2}$ pounds.

The 6-pounder spherical Manby's shot is rarely demanded, and is scarcely to be considered as a service projectile. It consists of a diaphragm shell filled with lead,[34] and having an iron loop fixed into it, to which is attached a thong similar to that of the oblong projectile. This shot has no fuse-holes. It is painted black before issue, and weighs about 8 pounds.

2. *Action of the Manby oblong shot.*

The action of the oblong shot is as follows: The end of a line[35] is made fast to the loop-hole of the thong; the rest of the line being carefully coiled either in a basket or upon the ground or deck,[36] and a fuse (Plate XXXIX, Figs. 1, 6) is placed in each of the four holes made for the purpose.

The fuses being uncapped, the projectile is placed in the piece[37] with

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[29] For the actual dimensions, see Plate XXXVIII, Fig. 2.

[30] This roughing is not effected in the same way as in mortar shells, by means of a sort of thread, but is done by cutting a number of shallow grooves about 0.2 inch apart around the sides of the holes.

[31] The hide is prepared with lime, and is technically known as "horse-hide-raw-lime." The strips are cut with a tapering toward each end, so as to give the required taper to the thong when completed. In the history of this projectile it has been mentioned that Captain Manby tried several materials for the thong before he adopted hide, and it is deserving of notice that Captain Jerningham, R. N., who carried on a large number of experiments with the apparatus, preferred manila-rope thongs to hide. In a report upon the subject he says, "Strops of manila rope were found to be the most serviceable."—(Captain Jerningham's report, Her Majesty's ship Cambridge, Devonport, April 27, 1860.)

[32] In a 4-plait of double hide. The hide known techically as "white horse," or "whit leather," is used for this purpose; it is the same material as is used for whip-thongs. Until 1863 fine wire was used for this purpose; hide is preferred to wire because the latter had a tendency to cut the thong.

[33] It was not woolded until 1863; by woolding the end, any chance of the line being cut is diminished.

[34] Diaphragm shells are used because there are no other shells of this caliber; and it has not been thought necessary to manufacture a separate projectle, when a diaphragm shell answers the purpose perfectly well.

[35] The line generally used is a "deep-sea line"; but there is issued with each apparatus 113 fathoms of $1\frac{1}{4}$-inch rope. (See War Office circular 793, par. 633.)

[36] The coiling of the line so that it may run out free without check is a matter of considerable importance. There are several ways of coiling it: in a basket, or, if the beach be even and free from large stones, as follows: the length of the fakes not to exceed two yards (Fig. 1, Plate XLIX), as if they are longer the rope is more liable to be broken "by the proportionately increased vibration."—(Instructions for the use of Manby's apparatus.)

Another way, as used in the whale-fishery, is as follows: [Shown in Fig. 2, Plate XLIX.—D. A. L.]

A third method, called "chain-faking," is sometimes employed. [See Fig. 3, Plate XLIX.—D. A. L.]

A fourth method is shown in Plate XL, Figs. 1, 2.

[37] A $5\frac{1}{2}$-inch (Coehorn) mortar specially prepared (with a crutch for firing quill-friction tubes), was used for projecting these shot (see W. O. C. 793, para. 598) until 1866, but by 21-2-66, 51-20-8742, it was intimated that metal friction tubes might be used with them. On an emergency they could be fired from a 24-pounder gun or howitzer.

its base toward *the muzzle*, and upon the discharge of the piece carries out the line, one end of which being retained, a communication is thus established between the vessel and the shore. The use of the hide thong is to remove the line from the immediate flash of the discharge, and so prevent it from being burned.[38]

The fuses serve, by the bright light which they give forth, to indicate the path of the shot and guide the firing party in laying the piece. The strength and direction of the wind must be considered in determining the direction to be given, the trajectory being affected by them to a very great extent, owing to the influence which the wind has upon the line.

With deep-sea line, and with the ordinary charge of 12 ounces, the range varies from 400 yards downward, according to the strength and direction of the wind.[39]

The 6-pounder is used in the same way, with the exception that, having no fuses, the operation of fixing and uncapping them is dispensed with.[40]

These projectiles are mainly used to establish a communication between the shore and a stranded vessel,[41] but the principle is applicable to a variety of other purposes, &c.

3. *Charges for Manby's shot.*

The maximum charge for the 24-pounder oblong Manby's shot is only 12 ounces, giving, with 45° of elevation, a range from 400 yards downward, according to the strength and direction of the wind.[1] If a higher charge is used, the line is generally broken.[2] There are no data on the subject of the charge for the 6-pounder spherical Manby's shot. ("Ammunition (English), 1867," by Captain Majendie, R. A.

[38] To connect the rope to the shot, and prevent it from being burned by the "powerful inflammation at the discharge of the mortar."—(Observations with directions on the method brought into use by G. W. Manby.)

[39] In some experiments carried on in the Royal Laboratory, 1859, with a charge of 12 ounces, elevation 45°, the range varied from 260 to 400 yards.

"For the Manby 24-pounder cylindrical shot the charge is 12 ounces, giving a range of about 300 yards."—(Captain Frazer's Notes on Matériel, p. 6.)

In Captain Manby's *Observations, with Directions, &c.*, he gives the following charges and ranges for the spherical 24-pounder shot. (As this shot consisted of a shell of 5½-inches caliber filled with lead, it must have weighed considerably over 24 pounds, and probably was about the same weight as the present oblong 24-pounder).

Charge.	With deep-sea line.	With 1½-inch rope.
8 ounces	220 yards	180 yards.
10 ounces	270 yards	220 yards.
12 ounces	320 yards	250 yards.

It also appears that in the determination of these ranges the most unfavorable conditions had been taken, for in another part of his Observations Captain Manby says, "An iron mortar * * * will project a 24-pounder shot, with an inch and a half rope attached to it, 250 yards, or a deep-sea line 320 yards, *against the utmost power of the wind.*"

[40] No charge is laid down for the 6-pounder, nor are there any data to enable me to assign even approximate charges and ranges to this projectile.

[41] With respect to this, the natural and simplest application of the projectile, the value of the invention will be more readily perceived if we bear in mind that "the most fatal cases of shipwreck and the most frequent are those which occur within the distance of from 300 to 60 yards off the land."—(*Observations, &c.*)

Captain Manby quotes several instances in which lives have been saved by his apparatus; and doubtless our naval annals and the records of the board of trade would afford many other instances of its successful application.

[1] *Vide supra*, foot-note 39.

[2] In some *experiments* which were carried on in the Royal Laboratory at Woolwich in 1859 with elongated 24-pounder Manby's shot and deep-sea line, the line broke with a 1-pound charge. With a stouter line than deep-sea line (1½-inch rope, for instance) a heavier charge might perhaps be used.

4. *Fuse for Manby's shot.*

a. Old pattern fuse.

The Manby fuse was adopted at the same time as the Manby shot, viz, about 1859 or 1860, but no *official* approval of the fuse is to be found until 1862. An alteration was effected in this fuse in 1864, when the present pattern with paper lining was introduced. (Ammunition, 1867 (English),p. 238.)

b. New pattern fuse.

The fuse for Manby's shot[1] (Plate XXXIX, Figs. 1 to 6) is a frustum of a large mortar-fuse cone, taken at its thickest part,[2] and rather over three inches in length. The composition bore is concentric with the longer axis of the fuse, and is considerably larger in diameter than that of the mortar fuse,[3] in order to increase the quantity of burning composition and the illuminating power of the fuse. The composition bore is lined with a hollow cylinder of rolled paper,[4] to prevent the fuse exploding on the principle of a tube, in the event of the wood shrinking away from the composition.[5] The composition bore is pressed[6] or driven with 2.5 inches of solid fuse composition, matched (Plate XXXIX, Figs. 1–5), primed, bored into, and capped (Plate XXXIX, Fig. 6), like a large mortar fuse.

The Manby fuse contains no side holes or powder-channels, not being intended to be prepared for any particular time of burning. The position of the first and second inches are indicated by rings cut round the fuse.

The fuse is painted drab all over, except the cap, which is not painted; a black ring is painted round the junction of the cap and fuse.

They are marked with the numeral, number of thousand, and month and year of issue in the usual way.

These fuses are intended for use with Manby's 24-pounder[7] life-saving apparatus at night. They are placed in the holes prepared in the base of the shot, four fuses in each shot, and being uncapped, become ignited by the flash of the discharge, and serve to distinguish the path of the shot through the air and indicate any error that there may be in "laying." Strictly speaking, therefore, they are rather lights than fuses.[8]

The Manby fuses are issued in zinc cylinders, 16 in each, with a paper containing the following printed directions for use:

> Fix the fuses firmly in the shot with the mallet and setter. Remove the caps from the fuses by giving the tape a sharp pull, when the shot is ready for firing.
>
> NOTE.—Care must be taken to protect the priming of the fuse from moisture.—(Ammunition (English), 1867, p. 270.)

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[1] Present pattern (with paper lining), adopted 14th February, 1864.—[War Office Circular No. 1 (new series), par. 875. Respecting adoption of original pattern, see *supra*.—D. A. L.]

[2] As nearly as possible, the largest diameter of the mortar fuse is 1.565 inches; that of the Manby fuse, 1.59 inches; the development of cone of the two fuses is the same.

[3] The bore of the mortar fuse is .37 inch in diameter, that of Manby's fuse .75 (measuring outside of paper lining), or .6 inch (measuring inside of paper lining).

[4] 100-pound paper.

[5] "I find, in consequence of the largeness of the bore for the composition of the Manby fuse, the wood is liable to shrink, and thus cause the fuse to explode instead of burning. To obviate this I propose to insert a paper lining similar to that used in my naval time-fuse."—(Letter from Colonel Boxer to Director of Ordnance, 21 January, 1864.) This alteration was adopted 14th February, 1864.—(War Office Circular No. 1 (new series), par. 875.)

[6] By hydraulic pressure.

[7] The 6-pounder Manby shot have no fuse-holes.

[8] These fuses burn 12½ seconds. Limits 12 to 13 seconds.—(Ammu., 1867, p. 286.)

[N. B.—Some unimportant foot-notes have been omitted in making this extract.—D. A. L.]

CHAPTER II.

FRENCH LIFE-SAVING GUNS AND PROJECTILES.

The French life-saving service is in the hands of the "Société Centrale de Sauvetage des Naufragés," and according to Capt. R. B. Forbes, of Milton Lower Mills, Mass., this society only dates back to 1865.

Two pieces of ordnance, "le perrier" and l'espingole," have been used by the French society for projecting lines over shipwrecked vessels.

Below are given the principal weights of these guns, projectiles, and charges, together with the greatest ranges obtained by an experimental commission of French officers in 1866.

Le perrier.

	French.	English.
Weight of gun	83 kilos.	182.98 pounds.
Elevation	30°	30°
Weight of powder charge	140 grams.	4.93 ounces.
Weight of projectile (flèche)	5 kilos.	11.02 pounds.
Extreme range	325 meters.	355.43 yards.
Deviation	17 meters.	18.59 yards.
Diameter of shot-line	4.5 millimeters.	0.1773 inch.

L'espingole.

	French.	English.
Weight of gun	20 kilos.	44.09 pounds.
Elevation	25 degrees.	25 degrees.
Weight of powder charge	50 grams	1.76 ounces.
Weight of projectile (flèche)	2 kilos.	4.4 pounds.
Extreme range	180 meters.	196.85 yards.
Deviation	36 meters.	39.37 yards.
Diameter of shot-line	4.5 millimeters.	0.1773 inch.

In their report of November 17, 1866, the French commission appointed to consider the subject of life-saving apparatus expressed the opinion that *le perrier* with a projectile weighing 5 kilograms (11.02 pounds) and 140 grams (4.93 ounces) of powder, for ranges of 300 meters (328.089 yards), and *l'espingole* with a projectile of 2 kilograms (4.4 pounds) and 50 grams (1.76 ounces) of powder, for ranges of 180 meters (196.853 yards) and below, would be sufficient for all their needs. The French recognized the fact that a line 4.5 millimeters (0.1773 inch) in diameter will require a larger line to be hauled out to the wreck before attaching the "whip" or hauling-line.

Delvigne's gun.

More recently M. August Delvigne invented a gun for projecting line-carrying arrows. The following description of this piece is taken from Capt. R. B. Forbes's work entitled "Life-boats, projectiles, and other means for saving life," published in 1872.

> The new piece of ordnance got up by Delvigne, weighs only 20 kilos., is made of gun-metal, almost a straight cylinder, about 18 inches long, and has an iron tail-piece screwed into the breech and jointed, so that in firing it is simply thrust into the soil until the square breech brings up; the elevation is regulated by a quadrant and plummet put into the muzzle; the bore is about 1¼ inch, or half that of the perrier; the piece carries wooden arrows, fitted with an iron tail to reach the charge, and at the muzzle these are much larger than the tail-piece, so that the shock of the explosion operates on the square base of the arrow, which is protected by a ring of metal.
>
> In loading this piece a vacant space is left as in the others (*le perrier* and *l'espingole*), and the cartridge is fired near its outer end; the piece being very short, this brings

the vent about in the center of the length. The iron arrows are about one-third longer than the gun, and about half the length of the arrow is in the gun when ready to fire. The advantages claimed by Delvigne in this little piece over the long *perrier* and *l'espingole* are its cheapness and portability, while with sufficient charge it gives an equal or better range; besides the wooden and iron arrows he fires a wooden arrow out of the *perrier* or almost any gun, which has cross-bars of round iron made malleable to resist the shock. These cross-pieces are fixed at right angles to the arrow, near the outer end, and are about as long as three diameters of the arrow. It is found that in firing this, the cross-pieces are bent to an angle of about forty-five degrees with the plane of the arrow, and thus form an anchor or grapnel, useful for many purposes. I saw one projected at Vincennes about two hundred yards from a four-pound rifle-gun, which held on to the soil sufficiently to have broken the line of about inch stuff.

Having briefly described the various arms in use in France for casting lines, it becomes necessary to go a little into detail as to the means of attaching the lines, which without due knowledge and practice of the system will be quite useless.

The wooden "flèches," or arrows, are made both round and eight-square; the former must be accurately turned and the latter planed true; therefore the latter are more simple and easy to make on board ship, or on shore.

The "coulant," or, literally, *slider*, consists of half a dozen turns of line put on something, as a whipping is put on a rope, only the ends overlaid by the rest must be left out, so that the turns can easily be pulled taut; much depends on this being done right; if the turns are too tight, the becket with its double bight and the line moves too slowly, and the "coulant" jams half way, causing the flèche to wabble and turn over; and if put on too loose, it runs down when the gun is fired, so fast as to break when it arrives at the projecting ferrule at the base. It is not too much to say that all depends on this being done right; the flèche should be slightly greased and the line either fired from a ball or from the ground, as in mortar exercise. Practice has made this so perfect that in France failures seldom occur from this cause.

Arrows of wood have the advantage of floating if they drop near the wreck, and of being readily recovered when they go beyond or fall short. The iron flèche is intended for long ranges or strong contrary winds. The distance depends so much on weather, on the amount of charge, elevation, and the line running clear, that I will only say it varies from 180 to 350 meters (196.85 yards to 382.77 yards).

In 1872 Delvigne's new gun, weighing 20 kilos. (44.09 pounds), gave a range of 300 meters (328.09 yards), with a wooden flèche weighing 8 kilos. (17.63 pounds), and a shot-line 8 millimeters (0.315 inch) in diameter.

CHAPTER III.

SECTION I. 3-INCH PARROTT MORTAR—SMOOTH BORE.

1. DESCRIPTION.

This mortar is the invention of Mr. R. P. Parrott, of the West Point Foundry, Cold Spring, N. Y. It is made of cast iron and lined with a steel tube. The piece is cylindrical about the seat of the charge, gradually tapering to the face of the muzzle. The breech is hemispherical. The trunnions are placed near the breech; their projection upon a plane through the vent and axis of the bore, being in front of and tangent to a plane perpendicular to that axis and containing the front end of chamber. The chamber has the form of the frustum of a cone.

2. SHOT.

The projectile is of cast iron, cylindrical, with the ends rounded. An eye-bolt is screwed into the base for the attachment of the line. The eye of this bolt is close to the base of the shot. The cylindrical portion is turned in a lathe so as to be almost a perfect fit for the bore.

3. SAFETY-ATTACHMENT.*

This contrivance consists of a piece of rubber, rectangular in cross-section, about 1′ long, 0″.75 wide, and 0″.5 thick, and of three or four galvanized-iron wires about 6′ long, laid parallel to each other, loosely twisted and coiled into a helix of from 18 to 19 turns. The rubber strap is sometimes placed inside the coil, and at others outside of it.

This combined strap and spring is interposed between the shot and line in firing. The object of the combination is to absorb the shock of the discharge and thus prevent the breakage of the line, by letting the first jerk come upon the rubber, which will generally break, and then upon the coiled wire spring. The wires will be straightened out before the full strain falls upon the line.

4. DIMENSIONS, WEIGHTS, &C.

3-inch R. P. Parrott mortar.†

Exterior diameter at breech	8.2	inches.
Exterior diameter at muzzle	5.8	inches.
Steel tube: Thickness of walls	0.6	inch.
Thickness at bottom of chamber	1.4	inches.
Thickness of cast iron at breech	3	inches.
Total thickness of metal at breech, iron and steel	4.4	inches.
Diameter of bore	3	inches.
Chamber, frustum of cone: Length	0.9	inch.
Greatest diameter	3	inches.
Least diameter	1.4	inches.
Weight of mortar	201.5	pounds.
Weight of carriage, or bed, wood, about	65.5	pounds
Total weight, mortar and bed	267	pounds.

Projectile.

Length	14.95	inches.
Diameter, scant	3	inches.
Weight with safety-attachment	24	pounds.

The writer is indebted to Mr. Kemble of the firm of Paulding, Kemble & Co., for the above information in regard to the Parrott mortar.

5. EXPERIMENTS WITH 3″ PARROTT MORTAR, MADE AT THE WEST POINT FOUNDERY, COLD SPRING, N. Y., JUNE 20, 1877.

This trial took place under the immediate supervision of Capt. J. H. Merryman, U. S. Revenue Marine, inspector of the life-saving service, and in the presence of Mr. S. I. Kimball, of the Treasury Department, general superintendent of the United States Life-Saving Service. The writer also was present.

a. Firing-ground.

The firing was done over a marshy piece of ground; the mortar being placed upon a raised platform near the edge of the marsh. A flag was

*This device was invented by Capt. Douglas Ottinger, of the Revenue Marine, in the course of his experiments at the West Point Foundry. It is referred to by Mr. S. I. Kimball, in his "Annual Report of the Operations of the United States Life-Saving Service, 1876," p. 24.

†Mr. Parrott constructed two mortars of larger caliber, one for the station at Peaked Hill Bar and the other for a station adjacent to it, upon Cape Cod, Mass.

The following data are available in regard to these two mortars, viz:

Caliber, 3.5 inches; weight of mortar, 300 pounds; weight of bed, 222 pounds; total weight of mortar and bed, 522 pounds; weight of projectile, 33 pounds; charge of powder, 8 ounces; range, 496 yards.

posted 400 yards distant, to indicate the direction to be observed in pointing. After each shot a man was sent out to measure the deviation from the line of fire and to ascertain the range of the shot. The platform for the mortar was made of loose earth overlaid with 2-inch plank placed parallel to the plane of fire. Its arrangement and lack of solidity was such as to make the recoil of the piece appear more severe than it would have been under more favorable circumstances. The mortar platform was over ten feet above the level of marsh.

b. *Pointing.*

The direction was given by the eye of the gunner, the elevation was obtained by means of a wooden quadrant and plummet. No great accuracy was observed in taking the elevations.

c. *Shot-lines.*

Three different kinds of lines were used upon this occasion.

1st. This was the smallest line—Diameter, 0″.22 (estimated). It was braided like sash-cord. It was manufactured by the Silver Lake Company of Newtonville, Mass. The material is linen thread. Its exterior finish was very smooth and hard. The length was 600 yards, and weight about 35 pounds.

2d. The diameter of this line was a little greater than that of the above. The material, Italian hemp; the length, 600 yards; weight, about 50 pounds. It was twisted in the usual manner. It is the kind heretofore employed in the service. It was manufactured by Cummings, of Philadelphia.

3d. An English rocket-line of Italian hemp, strands very loosely laid up; line very flexible. Diameter greater than that of either of the other lines. Length, 560 yards; weight, about 42 pounds.

d. *Charges of powder.*

These were measured, not weighed. Hazard's Standard "musket powder" was stated to have been used.

e. *Record of firings with 3″ Parrott mortar, at Cold Spring, N. Y., June 20, 1877.*

[Projectile, weight: 24 pounds. Elevation: 25° in every case. Kind of powder: Hazard musket.]

Number of round.	Powder charge.		Range.		Deviation of shot.		Kind of line.	Direction of wind with reference to line of fire.*	Remarks.
	Ounces.	Grams.	Yards.	Meters.	Right or left, yards.	Right or left, meters.			
1	4	113.40	370	338.33	17 L.	15.50 L.	Linen, Silver Lake (new).	W.	Light breeze.
2	6	170.10	350	320.04	10 R.	9.14 R.	Italian hemp (new)	W.	Light wind.
3	6	170.10	(Wire	broke.)	......	....	English rocket line	W.	Very light wind.
4	6	170.10	(Wire	broke.)	......	....	......do	W.	Barely perceptible.
5	6	170.10	281	256.95	6 R.	5.49 R.	......do	W.	Do.
6	6	170.10	434	396.85	6 R.	5.49 R.	Linen, Silver Lake.......	W.	Almost calm.
7	8	226.80	473	432.51	11 R.	10.06 R.	......do	W.	Light wind.

* The force and directions of the wind are approximations only, being estimated.

f. Action.

First shot.—Silver Lake linen line ran out beautifully, without kink or knot. Shot kept point first in latter part of trajectory. Recoil of mortar and bed about 6 feet.

Second shot.—Recoil, 7 feet; tore up platform and slid up bank in rear.

Third shot.—Wire broke near the projectile. Recoil of piece, 6 feet. Projectile rotated about its shorter axis.

Fourth shot.—Recoil of mortar severe, upset carriage and broke it slightly. Part of line carried out, wire broke again; shot rotated about shorter axis.

Fifth shot.—Same line tied directly to the shot without the interposition of the rubber and spiral spring. Line carried out all right. Recoil severe, mortar and bed turning upside down.

Sixth shot.—Line tied to shot. Violent recoil, mortar and carriage turning upside down upon the platform.

Seventh shot.—Same line used (Silver Lake), and tied directly to the shot. Line kinked, a large knot being found about 100 yards from the point of firing. Probably due to bad faking. Recoil very violent, mortar jumping from platform and turning upside down.

NOTE.—In his later projectiles Mr. Parrott has changed the form of the base, making it more pointed, and drilling a hole through it for the attachment of the line.

g. Result.

In regard to the above record of firings with the Parrott mortar, Mr. Kimball, the general superintendent of the United States Life-Saving Service, says: "At the trial a range of 473 yards was obtained. In view of this gratifying result, twenty-five of these guns were ordered and have been properly distributed."*

[Copy from printed record.]

SECTION II.—IMPROVEMENT IN PROJECTILES.

Specification forming part of letters patent No. 175742, dated April 4th, 1876; application filed March 6th, 1876.

To all whom it may concern:

Be it known that I, Robert P. Parrott, of Cold Spring, in the county of Putnam and State of New York, have invented a new and useful Improvement in Combined Projectiles and Life-Lines; and I do hereby declare that the following is a full, clear, and exact description of the same, reference being had to the accompanying drawing, which forms part of this specification.

This invention relates to those means for saving life by establishing communication from the shore or elsewhere with a vessel which has been wrecked, in which a shot or projectile having a line attached to it is thrown from a mortar. Ordinarily a round shot, having the line attached to it by a coiled wire, has been used for said purpose, but there has always been a difficulty in reaching a distant vessel, as the charge of powder, if increased, is apt to break the line at its attachment to the shot. In order to get greater range without thus exposing the line to breakage or disconnection, numerous attempts to attain the desired end

* See "Annual Report of the Operations of the United States Life-Saving Service for the fiscal year ending June 30, 1877," p. 40.

have been made with an elongated shot, which, owing to the reduced resistance it presents to the air over or as compared with the round shot, has a greater range for a given charge of powder. But in the previous use of elongated shots for the purpose practical difficulties have arisen, either as regards the disposition or connection of the line and in other respects, which have involved so much complication or otherwise been so defective that objections have been raised to the use of them.

My invention not only obviates these defects, but combines, in the use of an elongated projectile for the purpose named, cheapness, facility, and efficiency. Thus I use a simple or plain elongated projectile, having no groove cut lengthwise in it for reception of the line, as in a certain other method, but I attach the line by its coiled wire to the point or front end of the elongated projectile as inserted in the mortar, so that, when firing, the check which is produced as the shot feels the draw of the line causes the shot to be turned over end for end. This, by reason of the elongated form of the shot, materially eases the strain or reduces the first shock upon the line's attachment to the shot, and the shot, which draws the line after it, goes perfectly true to its destination. In this way, or by these means, I get a long range, and avoid breakage of the line's attachment to the shot, also secure a true travel for the latter.

In the accompanying drawing (Plate L), Fig. 1 represents a longitudinal section of a mortar with an elongated projectile, having a life-line attached, and as about to be thrown, the whole being constructed in accordance with my invention. Fig. 2 is a view on a reduced scale, showing the projectile after it has been turned end for end as it first feels the draw of the line upon it, and showing said shot with its attached line in the course of its flight. In Fig. 1, A is the mortar; B the elongated projectile, having the line C connected, through the interposition of a spring or coiled wire D, with the forward end of the shot as the latter is inserted in the mortar; and E is the charge of powder by which the projectile, with its attached line, is thrown from the mortar, said line being laid in a loose coil outside of the mortar. In Fig. 2 the same letters apply to like parts, but the shot has been turned end for end as it first feels the draw upon the line.

It is not necessary that the coiled wire D should of itself be the spring or only spring interposed between the end of the projectile and the line, inasmuch as a rubber strip or spring, F, may be independently applied to connect the line with the projectile and such elastic strip or spring be passed through the coiled-wire connection D.

I claim—

The combination with the elongated projectile B of the line C and interposed spring or coiled wire D, applied to connect the line with that end of the elongated projectile which is forward or outermost when the projectile is inserted in the mortar, substantially as and for the purposes herein set forth.

ROBERT P. PARROTT.

Witnesses:
HENRY JAYCOX.
ALEXANDER SKENE.

CHAPTER IV.

HUNT'S LIFE-SAVING APPARATUS.

SECTION I.

Mr. Edmund S. Hunt, of Weymouth, Mass., has invented a line-throwing apparatus, intended for life-saving purposes. A full description of this invention is given below in the specification forming part of the letters patent and in the letter from Mr. Hunt to the Secretary of the Treasury, dated February 7, 1878.

The writer was present at several trials of this projectile. The results of his observations will be found upon subsequent pages.

IMPROVEMENT IN LINE-THROWING APPARATUS.

Specification forming part of letters patent No. 203274, dated May 7, 1878; application filed January 25, 1878. (See Plate LI.)

To all whom it may concern:

Be it known that I, Edmund S. Hunt, of Weymouth, in the county of Norfolk and State of Massachusetts, have invented certain improvements in line-throwing apparatus, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, making a part hereof.

My invention is more especially designed for throwing a line from the shore to a wreck or from a wreck to the shore, but is, of course, adapted to other uses.

The drawings illustrate a shot having my coil-case applied to it, also one of my hand coil-cases, and also a line-support attached to the gun.

The distinguishing characteristic of my invention consists in the projectile made up of a short heavy shot and a long light case containing the line, the case being open at the mouth, and the projectile adapted to be fired with the shot next to the powder and the coil-case at the mouth of the cannon, and to reverse itself soon after it leaves the gun.

The minor features of my invention relate to the mode of coiling the line and the mode of holding it and of preventing injury to it from the gases which escape from the mouth of the gun.

In that form of projectile shown in the drawings, A is the powder, B the shot, C the coil-case, and D the coil. E is a wooden mouth-piece attached to the case C, in order to make it sure that the sharp edge of C shall not injure the line.

The end *d* of the line is, where a light line is used, attached to a short piece of stouter line, d^2, the line d^2 being less likely to be injured by the escaping gases, &c., near the mouth of the gun when fired. For a like reason the line d^2 is supported, as shown, by the supporter G, which prevents it from lying directly across the mouth of the gun, that being the most unfavorable position for it.

The coil is formed by winding the line upon a mandrel, the line passing through a vessel containing melted paraffine or other like substance, and also passing through a proper tension mechanism, to make the coil compact. A single coil is first wound of the desired length; next a

second coil over but the reverse of the first; then a third like the first but over the second; then a fourth like the second but over the third, and so on, forming a compact cylindrical coil, containing the desired length of line, the size of coil varying, of course, with the length and size of the line. The hand-coil is made in the same way. After the coil is put in the case a small amount of melted paraffine is applied between it and the case, and it is thus held securely in the case.

I propose in practice to make the hand-coil of considerably heavier line than the shot-coil, using for the hand-coil the line d^2.

I prepare my improved apparatus by putting the hand-coil and shot-coil mouth to mouth and covering the joint with a short metal cylinder, and make the whole water-tight by a proper casing.

To use the apparatus, separate the hand-coil from the projectile, load the projectile mouth outward, place the line d^2 over the supporter G, as shown, and hold the hand-coil in the hand, its mouth in the same direction as the mouth of the gun. When the gun is fired, only a small portion of the line from the hand-coil will be drawn out. The length of coil in the shot should be considerably in excess of the travel of the shot, which will, of course, depend upon well-known principles.

I am aware of patent No. 23726, of 1859, to Trowbridge, which describes a sounding apparatus on a principle closely analogous to the principle of my new projectile; and I disclaim all that is described and shown in that patent.

I am also aware of the French patent to Delvigne, A. D. 1847, vol. 10, plate xlii, which shows a shell or hollow shot with a coil of line and a hole at the base of the shell through which the line extends. This I disclaim, as my projectile has the coil-case at that end of the shot farthest from the powder, and the mouth of the coil-case is at its front end when the shot is in the cannon, the shot proper being so much heavier than the coil-case and coil that when fired the projectile will reverse itself as soon as it leaves the gun, that is, when loaded the shot is behind the coil-case and the mouth of the case is forward, but during nearly the whole of its flight the shot is in front and the coil-case behind it, the mouth of the case being then at the rear of the projectile. In this way the coil-case can be made of sheet-metal, which is altogether too weak to resist the shock of the explosion, and the center of gravity of the projectile be brought very near the powder, thus protecting the coil and coil-case from the shock and from the gases without the use of a sabot or any other contrivance, besides greatly reducing the cost of the projectile.

What I claim as my invention is—

1. The projectile above described, composed of the shot B and coil-case C and coil D, the coil-case being open in front, and the shot B being much heavier than the coil-case and coil, the whole constructed and arranged substantially as shown, and adapted to be fired with the mouth of the coil-case outward, and to reverse itself as soon as it leaves the gun.

2. The coil composed of a series of coils, packed with paraffine or its equivalent, substantially as described.

3. The supporter G, in combination with the gun H, substantially as and for the purpose specified.

4. The improved mode of throwing a line above described, consisting in using a hand-coil in connection with a shot-coil, the latter coil being in a case or holder forming a part of and traveling with the shot, and the former coil being held stationary, the lines composing the two coils being joined together at their contiguous ends, all as above described.

SECTION II.

[Mr. Hunt's letter to the honorable Secretary of the Treasury.]

WEYMOUTH, MASS., *February* 7, 1878.

SIR: Inclosed is a copy of my shell (3-inch) for carrying a line for life-saving purposes, a description of which I will now give.

The case of the shell is made of tin, with wings of the same. In the end is cast a leaden shot, made so as to fit the gun accurately without windage. The tin shell contains the line, wound, as the model shows, in the closest possible space. The line being prepared in paraffine and drawn from the center, comes out without fouling and without any drag on the shot, it traveling about as far with the line as without it. The wings are to keep the shell in line, and in so doing goes a much greater distance than if turning in the air. The coil, No. 2, I hold in my hand when the gun is fired, between which and the shell is a stout cord connecting the two small lines. On my gun is a rod carried out from the gun, in a line with the bore, with a fork or crotch in the end, that this connecting line is carried over, saving the line from breaking at the moment of discharge. The coil in the shell is the same as the 2-inch, only there is much more line in the shell.

In using, I place the powder in the gun, and put in the shell, shot end down; then carry the heavy line over the rod and hold the coil No. 2 in my hand, and apply the match. The result is this: the shell leaves the gun and immediately turns over and takes its course, the line paying out from it until it strikes the object intended. The explosion of the powder seems to throw the heavy cord that connects the two lines some two or three hundred feet from the gun, and then you find the end of line in the shell, so that a small part of the line is taken from the hand; and that is taken out by the fire explosion, and after the shell has reached the ground and the line being in the air, in falling draws from the coil. A shell, size of the model, will carry a line, size of one now in it, 1,000 feet with ¾ ounce powder at a very low elevation; with a shell of 2-inch diameter, and a charge of 2½ ounces powder, a range of one-half mile, carrying the same line, which, though being smaller, is very strong, being the same used by me for drawing a rope of sufficient size to tow a hawser in an exhibition before the Humane Society at Hull last week.

In this method of throwing line a sufficient amount of line to reach the object, must be always coiled in the shell, as, if the wind is directly ahead, but little, if any, line will be taken from the hand, and the slack of the line will fall behind you. For this reason it is always better to have ready more line in the shell than what is wanted for the distance the shell goes; a side wind taking up more line than a head wind, or one with you.

The advantages I claim over the old methods are these:

1st. The line has no effect on the direction of the shell, it simply paying the line out, the shell going as directed with a side wind as with one with it.

2d. The shell goes seemingly as well with the line as without, so that distance is overcome very easily.

3d. The gun is a very small affair, my largest 3-inch gun for experiments weighing but 30 pounds. One that has thrown a shell and line ½ mile weighs 10 pounds without the carriage.

4th. The lines are all put up in paraffine, so that the weather cannot injure them from wet, cold, or heat.

5th. The whole affair, gun, shell, and line, can be carried by one man, requiring neither horse nor carriage.

Very respectfully, your obedient servant,

EDWARD S. HUNT.

Hon. JOHN SHERMAN,
Secretary of the Treasury, Washington, D. C.

N. B.—The above is a transcript of an official copy of Mr. Hunt's letter.—D. A. L.

SECTION III.—TRIALS OF HUNT'S APPARATUS.

I. FIRST TRIAL.

The first trial of this apparatus in the presence of the writer occurred at Weymouth, Mass., during the latter part of February, 1878.

The following is an abstract of a report of that trial made to the General Superintendent of the Life-Saving Service:

1. *Firing-ground.*

The firing-ground was very uneven, was covered by a growth of bushes and trees, and was intersected by a strip of swampy ground. At the point where the shot usually fell the ground was considerably higher than it was at the firing-point. A flag was placed at (an estimated) 400 yards' distance from the guns. This flag was on or near the crest of the hill. No range had been *measured.*

2. *Guns.*

There were two of these:

1st. A 2-inch caliber, weight about 10 pounds; length of bore about 12 inches. This piece was made of a short length of "drawn" brass tubing and had a reinforce of steel or wrought iron around the breech. The breech-plug was a piece of cast iron fastened to the cylindrical portion of the gun by two wrought-iron pins.

2d. This gun had a caliber of 3 inches; its length was a little greater than the 2-inch gun, and its weight was about 40 or 45 pounds.* It also was made of brass tubing. It had two reinforcing bands, the inner of steel or wrought iron, the outer one of brass. The cast-iron breech-plug was held in position by pins. It was stated by the inventor that these guns were only temporary contrivances to show the principle of his invention.

Though the whole gist of his invention is contained in his projectile, it has been deemed necessary to a definite understanding of the subject to give some of the more prominent correlative details.

3. *Projectiles.*

These were tin cylinders with leaden heads cast upon them. The coils of line were stored inside the shells. The total length is between 16 and 18 inches. Two-inch and three-inch calibers were used. The 2-inch shell with line weighed about 7 pounds, the 3-inch with line about 10 pounds.

* The above weight, 40 or 45 pounds, was the one given me by the inventor on the date of trial. It may be noted that in his letter to the Secretary of the Treasury the inventor states the weight of the 3″ gun to be "but 30 pounds." It is probable that the latter was the weight before the outer reinforcing band was added to the gun.—D. A. L.

4. *Shot-lines.*

Two sizes of lines were used. The smaller line was made of pack-thread and used in the small shells. The larger line, used in the 3″ shells, weighed about 3 pounds. After firing it appeared to be about the size "Silver Lake No. 3½." The material was linen thread, loosely laid up in three strands, without much twist.

The lines were put up in coils 6 inches long and were saturated with paraffine. The lines were prepared for use by coiling around a spindle placed in a lathe. The ends of the lines in the coils were tied together, after which the coils are inserted in the shell one above the other, three in all. A similar coil was held in the hand of the operator when about to fire. The ends of the lines in the shell and hand coil were made fast to the extremities of a larger piece of line (No. 7) about three feet in length, which was passed over the line-supporter that projects over the gun. This device is to prevent the burning off of the small line by the escaping gases at the instant of discharge.

5. *Powder.*

The Oriental Powder Company's "Duck" powder was used for firing. Charge, 2½ to 3½ ounces, by measure. No cartridge-bags were used.

6. *Recoil.*

As these experiments were only to test the line-carrying properties of the projectiles no gun-carriages had been provided. The guns were mounted in a notch or groove cut in a log. This piece of timber was imbedded in the earth flush with the surface; of course no recoil was apparent.

7. *Experiments.*

Five shots were fired.

1. This was with a 2-inch projectile and pack-thread fired from the small gun. The projectile, notwithstanding the "wings," turned over and over about one of its shorter axes. Range between 350 and 380 yards. A portion of the force of the powder was expended in blowing out the breech of the gun. The bowing or drift of the light line was considerable, though the wind was very light. The line paid out well from the coils.

2. Three-inch projectile from larger gun. Shot turned over three or four times and then proceeded point foremost. Shot deviated but little from plane of fire, but the line drifted badly. Range, estimated, nearly 400 yards.

3. Three-inch projectile used. Shot turned over two or three times Line paid out in bunches, from the coils catching on each other. Line did not drift so badly as in last shot; operator drew in part of the slack from the rear. Range about the same as the above.

4. Two-inch shot. Shot turned over once or twice and then kept point direct to the front. Range good, about 400 yards.

5. Two-inch shot. Projectile turned over twice, and attained a good range, estimated by those present at 600 yards. There was a difference of opinion as to where it fell. No one went out to see where it struck at the time. The writer thought it fell inside of 500 yards, but the shadow of the woods rendered the point of fall uncertain.

8. *Remarks.*

The line was not broken or cut in a single instance, and Mr. Hunt stated that it had never been cut during any of his experiments.

The first spring of the projectile into the air generally carried a portion of the line from the coil which was held in the operator's hand. After the reversal of the shot, the line was paid out from the coils in the shot.

There are two chances for the line to be carried out instead of one, namely: 1st, From the coils in the shot; 2d, From the coil in the hand in case the first line should foul in the projectile. The line was badly twisted by being drawn from the center of the coils, as every turn in the coil counted as one twist. This trouble has been obviated by Mr. Hunt, by winding the coils in opposite directions. It would not be easy to prepare the line for a second shot, as it would require a lathe to do the work expeditiously.

[NOTE.—Later, Mr. Hunt stated that in actual service he intended that the line and shot should be sacrificed after once firing, the value of which is a small matter as compared with a single human life.]

Mr. Hunt pointed out where various shots had fallen that had attained greater ranges than any procured during this trial.

The largest line used by Mr. Hunt upon this occasion had a breaking weight of 88.5 pounds, and a stretch of 3 inches in a length of 6 feet.

SECOND TRIAL.

The second trial took place at Weymouth, Mass., May 7–8, 1878. At this trial Mr. Hunt had a new gun, caliber 3½ inches. He stated that he had not weighed it, but gave its weight as "about 70 pounds" and the weight of the carriage as "about 80 pounds." The plan of the construction of the gun was similar to the 3-inch gun before described, but it was a much better gun. The reinforce band was of bronze. The carriage was made in two parts; the upper part of iron, in form, resembling a mortar bed as usually constructed; the lower part was a piece of heavy plank about 40 inches long, about 12 inches wide, and about 3 or 3½ inches thick. The iron portion was bolted to the wooden part. Rope loops fore and aft served as handles for transportation. The whole weight the inventor estimated at 150 pounds.

1. *Projectiles.*

Outside length	21.5	inches.
Inside of shell—length	19.	inches.
Diameter, exterior, little less than	3.5	inches.
Coil of line for shot, No. 4½—length	17.6	inches.
diameter	3.	inches.
Weight of shot empty	9.12+	pounds.
Weight of shot with line inside, about	15.	pounds.

The above dimensions and size of coil (for inside of shot) are those of the projectiles and coils used in the third series of trials at a later date. At the second trial at Weymouth some of the shells had more than one coil inside, probably three. For his later experiments with larger lines (Nos. 4½ and 7) Mr. Hunt used but one coil in the shot. After placing the line in the shot, a wooden plug with a hole in the center for the line to pass through was put in the shell over the cord and held in position either by indenting the tin case around it or by folding down the rim by a slight blow to prevent the plug from coming out when the shot was

reversed. These projectiles had a reinforce of galvanized sheet-iron around the lower end of the tin shell to strengthen it sufficiently to stand the shock of discharge without upsetting. There is about one inch of lead cast upon the head (point) of the projectile, and then 6 inches in length of the sheet-iron. The head is flat, the plane of its face being perpendicular to the axis of the projectile. Even this sheet-iron envelope does not prevent a certain degree of upsetting when large charges of powder are used.

Firing record at Weymouth, Mass.

Date.	No. of round.	Elevation, degrees.	Powder charge, ounces.	Size of line, No.	Wind, direction.	Range, estimated, yards.	Remarks.
1878. May 7	1	22½	3½	4½	W. W.	About 400	Shot rotated two or three times about shorter axis.
7	2	22½	4	4½		450	Shot rotated two or three times.
7	3	15	4	3½		400, 440	Shot rotated three or four times.
7	4	20	4	3½	Wind very light.	Over 400	Wind on May 7 very light and variable; wind blowing almost directly from the rear.
8	5	22½	3	3½		450	Velocity of wind = 6.66 feet per second = 4.49 miles per hour; flight of shot good; wind in rear; no sustaining-rod used.
8	6	17½	3	4½		380	Shot rotated three or four times; very little drift of line; wind light, and variable in direction; shot fell on soft ground; was picked up in good condition; velocity of wind after last shot = 9'.1 per second = 6.14 miles per hour.

THIRD TRIAL.

Firing record at Marblehead, Mass.

Date.	No. of round.	Elevation, degrees.	Powder charge, ounces.	Size of line, No.	Action of line.	Wind, direction.	Range, estimated, yards.	Remarks.
1878. July 2	1	25	3	3½	Good	W.	*400	Boats anchored 300 yards from shore.
2	2	24	3½	4½	....do	Wind very light.	Over 300	Shot rotated two or three times.
2	3	20	4	4½	Parted at a splice.		....	Parted line at a splice in hand-coil.
2	4	25	4½	7	Cut.........		....	Line parted 77 yards from shot; probably cut off by sharp edge of hole in plug at end of shot.
2	5	20	3	4½	Good		Over 300	

* These ranges are all estimated, but as they went beyond the line of boats, which were 300 yards out, no attempt was made to secure any greater accuracy.

First shot.—Line drifted to left about 20 yards at 200-yard range.
Second shot.—Line drifted to left but fell over boats.
Third shot.—Six hundred feet of line said to be in coil in shot.
Fourth shot.—Three hundred feet of line said to be in coil in shot.
Fifth shot.—Only about 20 feet of drift in line.

The trial at Marblehead, Mass., July 2, 1878, took place over water. Four boats were anchored end to end, 300 yards from the beach. The

boats were each 13 feet long, and were 23 feet apart, making a line of 121 feet long parallel to the beach, over which to throw the shot-line. The wind though very light, was from the right and rear. The gun was pointed over the boat on the extreme right of the line.

2. *Remarks.*

The shock of discharge is often sufficient to drive the wooden plug in the outer end of the shell down several inches; in one case, when measured, it was found to be six inches from the mouth of the shell.

Mr. Hunt uses lines which are termed "soft laid" from the manner in which they are put together without much tension upon the strands. These lines have no "finish" upon them when received from the maker, but are passed through melted paraffine as they are coiled upon the spindle. Seafaring men differ in regard to the manner of laying up cords for shot-lines. Some claiming that the lines should be "soft laid," others that they should bə "hard laid."

A "soft-laid" line is probably not so apt to be cut in hauling it across the side of a ship as the solid-braided line. It is however easily compressed, which for a small line makes it a little more difficult to grasp.

It is but just to Mr. Hunt to say that he has not yet perfected all the details of his projectile. At the writer's suggestion, the inventor laid aside the "supporting rod" attached to the upper side of the gun, and discarded the intermediate piece of large line which connected the coil in the shot with the hand-coil. These devices were intended to keep the line from being burned off at the instant of firing. No difficulty was experienced from their omission, as the shell projects about six inches beyond the muzzle of the piece; a sufficient distance to prevent the escaping gas from burning off the line. This projectile has a *flat* surface at the front end to oppose the wind in its flight. This form of head is objectionable on account of the increased resistance of the air which it develops. The form of the point of a shot has a great influence upon the intensity of the resistance which a projectile will experience in moving through the air. The following facts in regard to the further efficiency of this projectile should be made the subject of a more extended experimental investigation, namely:

1. The action of the projectile in windy weather, with both cross and head winds. This is especially desirable when it is borne in mind that the wind's force varies directly as the square of its velocity. "Thus, when the wind's velocity is 20 miles per hour, its force is four times as great as that of a wind blowing 10 miles per hour."

2. The maximum charge that may be used without upsetting the projectile.

3. The effect upon the strength of the lines by having a knot tied at the junction of the coils in the hand and shot. Knots are generally points of weakness.

4. The effect of the free use of paraffine upon the ease of handling.

It is probable that this projectile, from its lightness and compactness, may be best suited to carry on board vessels for use in cases of stranding. The wind, in such instances, is generally blowing on shore, and the small weight of the shot would not be such a serious disadvantage to it as when firing against the wind. It is a well-known fact that the heavier the projectile, for the same caliber, the greater will be the range, other things being equal. The mass of the Hunt projectile is rather small for the area of its cross-section, and it is constantly diminishing during flight. The ballistic capabilities of this projectile against a strong wind can only be demonstrated by experiment.

CHAPTER V.

CHANDLER'S ANCHOR-SHOT.

(Plate LII.)

In the Army and Navy Journal of April 27, 1878, page 607, the writer finds the following:

Capt. Ralph Chandler, U. S. N., has invented a shot which is intended for the use of ships on shore (aground), where the surf is too heavy for boats to land without the assistance of a line. It can also be used at life-saving stations to throw lines over beached vessels or vessels in distress. As an implement of war, it will be useful in waters where torpedoes are supposed to be located. A ship can anchor near the supposed torpedoes, throw the shot two or three hundred yards toward them, and haul it home, breaking such wires as it may encounter. It is very simple, and its simplicity insures its successful working, and its cost is very little more than that of an ordinary shot. It is merely a shot with hinged anchor flukes projecting from its sides and folding back into slots, so as not to interfere with the entrance of the shot into the gun. To the rear of the shot a chain or wire-rope is attached, and carried to the front of the shot through another slot.

In using it, the shot is to be inserted into the muzzle of the gun far enough to bring the ends of the arms inside the muzzle, the chain or wire rope attached to the rear of the shot brought out through the slot, the strap taken off, and the shot pushed gently home. The springs under the arms, always bearing or pushing them outwards, will extend the arms as soon as the shot leaves the muzzle of the gun or mortar, and a perfect anchor will be projected. If in its flight the arms are brought in contact with anything, they will close until the obstacle is passed, and where the shot lands, its holding power will be equal to any kedge anchor of the same weight. It appears to be a most useful invention. If the Huron could have landed a shot of this description, by it the balsa could have been hauled ashore with a hawser or large line attached to it. One of these shots made for an eleven-inch gun would have power enough to carry a two-inch rope ashore, and after the shot was once ashore and well hooked, all the boats of the ship could be hauled ashore without any other line.

The flukes of this anchor-shot are three in number, placed equidistantly around the circumference of the shot.

The writer has been informed that up to the present time (July, 1878) this projectile has not proved to be as satisfactory as was anticipated.

NOTE.—The above illustrations of the Chandler anchor-shot were taken from Harper's Weekly of June 15, 1878.—D. A. L.

The following account of experiments made with Chandler's anchor-shot has appeared in the Army and Navy Journal since the above was written:

Experiments were made with Chandler's anchor-shot off Paddock's Island, Boston Harbor, July 20, 1878. Gun, 32-pounder, of 33 cwt.; junk wad behind shot at each fire; size of line, 2¾ inches; whale line. Elevation of gun, 12°; wind across line of fire, moderate breeze.

Fires.	Weight of powder.		Weight of shot.	Length of line thrown straight.	Slack line.	Total fathoms.
	Lbs.	*Oz.*	*Lbs.*	*Fathoms.*	*Fathoms.*	*Fathoms.*
1	1		78	94	15	109
2	1	2	78	112	18	130
2	1	6	78	Line broke close	to shot.	
4	1	4	78	127	15	142
5	1	6	78	137	10	147
6	1	8	78	150	10	160
7	1	10	78	160	15	175
8	1	10	78	157	15	172
9	1	14	78	157	15	172

Towards the end of the experiment the line became soaking wet, which increased its weight to that extent that four ounces increase of charge in the last fire did not increase the range.

To make these experiments perfect, a new and dry line ought to be used at each discharge.

It is evident that with a heavy shot and a large calibered gun there is nothing to prevent four hundred fathoms of line being thrown. In the first seven fires a short section of wire rope was attached to the shot and the line spliced to that, but in the last two the line was fastened directly to the shot, and served with rope yarn well soaked in water. The line was not burnt in the least, and a large eight-oared cutter was hauled ashore by the line.—(Extract from Army and Navy Journal of August 10, 1878).

CHAPTER VI

LIFE-SAVING ROCKETS.

I. LIFE-SAVING ROCKET, BOXER, 12-POUNDER.[1]

(Plate XLI.)

The life-saving rocket.

Dennet's "twin" rockets were superseded by Boxer's on 15, 3, '65. This consists of two rocket bodies, one being fixed in prolongation of the other, to give great length of burning and flight, without any sudden violence, which might break the line which it carries,[2] or irregularity from uneven burning.

Thus it will be seen that "instead of making one cavity in the rocket, two cavities (*c c'*) are formed, the one behind the other, with a portion of solid composition (*b*) between them, so that when the solid composition (*b*) is burnt through, the front cavity (*c*) is ignited, thereby imparting to the rocket an additional impulse." The stick (*d d*) is fixed at the side of the rocket. The line (*e e*) is passed through a hollow at each end of the stick, as shown in the annexed cut (Fig. 1, Plate LIII), and the end of the line is secured by a common overhand knot; two India-rubber and one brass washer (*f*) are placed between the knot and the stick to reduce the effect of the sudden jerk which is given to the line when the rocket is fired. The arrangements for the use of this rocket are the same as those hitherto carried out with Dennet's rockets.

A second knot is usually made in the rope near the hinder end of the stick, in case the line should be burnt through by the flame issuing from the rocket.

N. B.—All Boxer life-saving rocket cases are protected from the action of the composition by an internal coat of anti-corrosive paint, consisting

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[1] Time of burning, about $4\frac{1}{2}$ seconds.

[2] General Boxer writes in letter of 25, 5, '65, that his object is "the continuance of the propulsion through a much longer period, without any excessive strain upon the line."

Captain Robertson, R. N., writes to secretary marine department board of trade, 9, 2, '65, that Dennet's rockets "frequently carry away the lines, and sometimes do not ignite; they are also double the expense of Boxer's rocket." Inspecting Commander Earle reports on a trial between Boxer's and Dennet's rockets: "Of the three double Dennet's rockets only one was any use; two broke their lines and struck the ground. The mean of the five shots with the Boxer rocket gave a range of 370 yards very true, and with much less strain on the line, as it never broke with Boxer's rocket." Reports from Inspecting Commanders Charles and James, from Yarmouth and Lydd, are confirmatory of this statement, 19, 10, '65. At Whitby, on 27, 3, '66, one of the Dennet's rockets, igniting before its twin rocket, came back and struck the inspecting commander.

Captain Robertson, in letter 9, 2, '65, reports that Dennet's rocket attained a greater range than Boxer's.

of copal varnish, ¼ pint; gold size, 1 pint; turpentine, 1¼ pints; white lead (dry), 7 pounds, being the same as is now applied to the interior of Hale's rockets. All rockets manufactured since 22, 9, '60, have their cases further protected by blackening by burnt oil.

BOXER'S LIFE-SAVING ROCKETS.

1. *Details of patterns.*

The pattern in the wood-cut known as Mark I was approved 15, 3, '65. Mark II, approved 9, '66, differs from mark I in having no hole to take the keep-pin through the "clip," the pin being passed through the stick in front of the "clip," because it was sometimes found troublesome to bring the hole in the stick and "clip" exactly to cover one another. The sealed pattern is nearly .5 inch shorter than Mark I, so as to enable the rockets manufactured to conform with it, it having been found that the act of pressing the composition slightly shortens the whole case; hence that of the dummy pattern was longer than the same case would be after pressing.[3] Mark III,[4] approved 1, 9, '68, differs from Mark II in having the case made of Atlas (*i. e.*, Bessemer) metal. All manufactured since October, 1870, have the vent covered with paper (instead of the serge plug). The paper is to be broken before firing. It is important to distinguish Pattern III clearly from I and II; the cases of rockets of the latter pattern having been found liable to deteriorate, and even to split, from their being taxed beyond their strength by the pressure of the composition, are ordered to be very carefully examined from time to time for rust spots and indications of cracks.[5]

Paint: formerly two coats of black varnish; since 5, 11, '70, two coats of red paint, for better protection.

The 12-pounder life-saving rocket stick[6] is deal, 9′ 6″ long, square, with corners shaved off; it is the same size from end to end. It is bound at the bottom end with an iron ring, and is plated at the head or front end with plates, which, as well as the stick at the front part, are hollowed to fit close to the rocket. The second or hinder plate is 3 inches long; it has a flange to rest against the base clip of the rocket. Over the half of the stick next the rocket is tacked a sheet of tinned iron for a length of fourteen inches, to protect the stick from the flame escaping from the rocket.

2. *Iron pin for life-saving rocket Mark I.*

This is an iron pin 1.2″ long, No. 8 Birmingham wire gauge; the end is bent over at a right angle, thus bringing the length down to .85″

3. *Brass washer.*

The brass washer shown in the wood-cut of the rocket * * * is 1″ in diameter, with a hole in the center .5″ diameter; they are about .15″ thick.

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[3] To prevent mistakes arising from comparing an empty pattern with a filled rocket

[4] The numeral marked on the pattern sealed as II was altered in place of sealing a new pattern.

[5] The crack is generally developed in a longitudinal line running parallel to and within one or two inches of the seam or joint of the rocket.

[6] Mark III stick is strengthened by having the part next the base of the rocket more covered by the tin sheet, which is also passed under and clamped by the iron socket.

4. *India-rubber washer.*

The vulcanized India-rubber washers referred to in the description of the rocket are both alike, each being 1″ in diameter, with a hole in the center .5″ in diameter; they are about .7″ thick.

II. Machine for firing life-saving rocket.

(Plate XL, Figs. 3, 4.)

The machine for firing the life-saving rocket consists of a bed to hold the rocket, in prolongation of which is fixed a pry-pole, and from the rear end of which spring two legs, one opening to the right and one to the left. Both bed and pry-pole are made of sheet-iron, the former being an open rectangular trough 3.2 inches broad[7] and 4 inches deep; the latter one, of more rounded form, being 1.65 inches broad at the top and 1.5 inches deep.

The front end of the pry-pole enters the bed for a length of 7 inches, the upper edges of the former standing about .2 inch above those of the latter, so that the bottom of the larger trough is 2.7 inches beneath that of the smaller, to allow for the rocket resting in the bed while the stick lies in the hollow of the pry-pole. The two troughs are fixed together by three rivets on each side, the spaces between them on each side, owing to their difference of width, being filled up by a piece of wrought iron, through which the rivets pass. The front edge of the bed trough is iron-strapped, and its remaining edges as well as those of the pry-pole trough are "wire-edged." With the exception of a strengthening bar running from bed to pry-pole, the rear end of the bed trough is left open beneath the front of the pry-pole, so as to allow of a free passage to the gas escaping from the rocket base. Two pieces of wrought iron 7 inches long are riveted along the after part of the sides of the bed, close to the angles formed with the bottom, their rear ends projecting sufficiently to allow of a bolt secured with a screw washer to pass through them, on which hinges a small flat piece of iron, taking two other bolts screwed and nutted, and each long enough to allow of a socket (ending in flanges) which admit the flat iron between them to be hinged on it. Thus the flat iron hinges longitudinally on a bolt transverse to the direction of the troughs; whilst the leg sockets move transversely on hinges longitudinally placed.

In each socket is fixed an ash leg with ferrule, having a foot projection and spike; while beneath the pry-pole runs a strengthening bar from end to end, which is at the hinder extremity bent down to form a ground-spike. In the right side of the bed is cut an opening to admit of the entrance of a portfire to fire the rocket, and behind this is fixed a brass quadrant plate, on which is hung a plummet and line to give elevation

On the left side of the bed, protected by a copper cover, is a strong lock of simple construction, with a lever trigger, to which is attached a line, led through one sheave on the left-leg socket, and another near the left foot. Near the right foot is fixed by two screws a strong strap and buckle to enable the two legs and pry-pole to be strapped together, for more convenient stowage when not in use.

Mark I trough or machine has long existed; it was sealed in November, 1865. This pattern has a very small block fixed to a ring near its left foot. It is difficult to pull the trigger-line from the right side, owing to the stiff movement of the little block.

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[7] Interior measurement.

Mark II was approved 21, 10, '70; it differs from Mark I as follows:

1st. The trigger-level is prolonged to a length of about 4 inches, so as to allow of the lock being worked with a lighter pull.

2d. The pulley-block on the left foot is replaced by a sheave of much larger size fixed through the middle of the wood (which is supported by a band); this pulley enables the machine to be fired from the right side.

3d. The opening in the right side of the trough is furnished with a sliding cover.

Mark III machine differs from the previous pattern only in having an arrangement for causing the flash from the detonating tube to strike direct up the axis of the rocket. This is effected by making the vent or channel for the tube in a circular form instead of straight across the machine.

N. B.—A spare spring is ordered to be supplied. A priming wire for life-saving rocket machine was approved on 20, 5, '70, and a pattern, Mark I, sealed. It is formed from iron wire No. 5, Birmingham gauge. It is about 4 inches long, being formed into a loop at one end. On 21, 10, '70, a pattern, Mark II, was approved, differing from Mark I in being twisted to form a screw at the part near the point. On 4, 9, '72, Mark III was approved; it is curved to fit the vent in Mark III machine. It is used to clear the vent of the life-saving machine of any portions of the quill tube that may remain in it after firing.

III. Stores, etc.

1. *Life-saving rocket-tube.*

The life-saving rocket-tube consists of a goose-quill body about 1¼″ in length, driven and pierced in the usual way. The large end of the quill is closed by a disk of tissue paper being varnished over it. Into the smaller end of the quill is secured with diamond cement a pigeon-quill about an inch long, which enters the large tube to a depth of about .1 inch. This tube is filled with detonating composition.[8] Round the extreme small end runs a small band of kamptulicon. These tubes are used for firing life-saving rockets. The body of the tube is inserted into the vent of the lock at the side of the machine, being held in its place by a small piece of brass which shuts on its neck just below the kamptulicon band. The descent of a spring-hammer edge crushes the detonating end of the tube and fires the same. They are packed, by the special request of the board of trade, in larger quantities than other tubes, viz, 150 in a (No. 27) tin cylinder, which is closed by a calico band attached by shellac over the junction of lid and body.

2. *Fuse for life-saving rocket, Mark I.*

This is 1″.5 long; it is made of paper; it contains an inch of ordinary fuse composition; it is conical in shape, and its sides are covered with kamptulicon, being brought up to fit the vent in the base of the life-saving rocket; it has a paper cap tied on with twine, which need not be removed before firing; it burns for about five seconds, and is required for use with the portfire.

[8] Detonating composition for quill friction tubes: Potash, chlorate of, 6 ounces; antimony, sulphide of, 6 ounces; ground glass, 1 ounce, 10 drams. Damped with varnish, of spirits, methylated, 1 quart; shellac, 357 grains, in the proportion of 75 minims to 1,000 grains of composition.

STORES CONNECTED WITH THE LIFE-SAVING ROCKET.

3. *Light for illuminating wrecks* (*Mark I*), *March*, 1874.

The light (Fig. 2, plate LIII) is about 28½ inches in length and 2.65 inches in diameter. It consists of a cylindrical case of 1 X tin sheet in 6 lengths of 4½ inches each, fitted together and connected by small bands of tin sheet, half an inch in width, soldered over each joint. The case is filled with the following composition, viz: saltpeter, ground, 7 pounds: sulphur, sublimed, 1¾ pounds; orpiment, red, ½ pound. One end is fitted with a piece of wood, with a loop of iron wire attached to it for suspending the light; the other end is primed with mealed powder, and covered with a kit plaster.

The stand is a simple tripod, consisting of three wooden legs about 6 feet in length, connected at the top by a piece of iron wire having a small hook attached to it, on which the light is suspended; there are three iron rods which are hooked to and connect two of the legs, forming an incline for the light to rest on, so as to hang in a sloping direction—not vertically downward.

The light, if hung as described, clears itself of dross when burning, and is kept further clear by the case separating at each joint, as the heat of the burning composition successively melts the soldering of the bands. The time of burning is about 30 minutes. This light must not be roughly handled or thrown about, as it is liable to be broken across at the junction of the segments. Care must be taken in removing the cap before lighting.

The case must be grasped firmly at the capped end whilst the cap is torn off by means of the string loop; if there is any difficulty in removing the cap it must be eased off round the edge by inserting the blade of a knife.

4. *Portfire, Boxer's, for life-saving apparatus.*

Differs from a common portfire in being 8 inches long and in being intended to ignite by means of a detonating primer, in the same way as the long general service light, the end being closed by a tin cap and a piece of kamptulicon, and strengthened by a tin band perforated to take the detonating primer, which enters into a small space beneath the kamptulicon. The composition is primed in the usual method with mealed powder, perforated in the center.

5. *Metal handle for long light, general service (Mark I), used with life-saving apparatus, Mark I.*

Consists of a hollow cylinder of tinned iron, fitting on to a wooden end; it is closed at the opposite end by a metal screw-cap, to which is hinged on, by means of a brass pin passing through two brass flanges so as to form a hinge, a copper-covered piece of wood, with six transverse cells, each to hold one primer.

6. *Handle for portfire used with life-saving apparatus, Mark I.*

Consists of a tinned iron cylinder closed across with tin and red lacquer, so as to form a socket to take the portfire end at one extremity held by a tightening screw. The body is hollow, closed with screw cap and piece of wood copper-covered and recessed with seven cells to take one detonating primer each.

7. *Tin box for life-saving rocket stores, Mark II.*

This is simply a tin box with a hinged lid. Length, 6".1; breadth, 3".6; depth, 3".0. On the lid is a label giving the contents, viz: 9 fuses, 9 detonating tubes, 9 iron pins, 12 India-rubber washers, 6 brass washers.

8. *Wood boxes for lights, &c., for life-saving apparatus, Mark I.*

These are two yellow deal boxes closed with hinged lids secured with hasps and staples; they have internal fittings to suit the stores. The larger one is 13".3 × 8". × 11".5, exterior dimensions. The smaller one is 12".2 × 6".2 × 11".5, exterior dimensions (the depth of both being the same). Their contents are as follows:

	Large box.	Small box.
Lights, long	10	6
Portfires	12	6
Handles, light	2	1
Handles, portfire	2	1
Detonating primers for lights	12	7
Detonating primers for portfires	14	7

IV. USE OF LIFE-SAVING ROCKET.

Instructions as to the use of the rocket, together with directions as to the formation of volunteer life brigades, the provision of requisite stores, &c., are issued by the board of trade in the form of a pamphlet, entitled "Instructions in respect of the Rocket and Mortar Apparatus for saving Life from Shipwreck." A short description of the method of using (Plate LIV) the life-saving apparatus generally adopted is here given, taken partly from this pamphlet and partly from information supplied by Captain Robertson, R. N., also Mr. John Foster Spence, Mr. Gilbert, and members of the Tynemouth Volunteer Life Brigade.

A suitable cart containing the necessary stores[9] is run down to the best position for action.[10] The machine is placed to stand as firmly as circumstances will permit; for a maximum range the trough should be laid from 35° to 38°, the box in which the line is faked being placed from about 6 to 9 feet to the rear, and 6 to 9 feet to leeward,[11] the top with the pins being taken out and the box slightly tilted with its mouth towards the front with the line lying in it, the end being threaded through the rocket-stick and knotted over the washers and also some way along the stick; [12] the lanyard by which the rocket is fired should be pulled by a man standing on the windward side,[13] the rocket being fired, if possible, by the tube without the fuse [14] in order that it may be discharged the instant a favorable opportunity is presented, which opportunity might pass while the fuse is burning.

It is very important, for more than one reason, to effect a communication with as few unsuccessful attempts as possible; not only is precious

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[9] See list of stores on a subsequent page.

[10] As the rocket cannot under any circumstances be expected to carry much over 380 yards (* * *), the choice of position must generally be very limited.

[11] The rocket stand may be capsized by the line running out if the line be laid to windward; the coil should be as little out of the line of flight as may be, for it is obvious that the pulling of the line tends to draw the axis of the rocket in the direction of a line passing from the center of gravity of the rocket to the spot where the rope is coiled. That the position of the coil of rope affected the flight of the rocket considerably was pointed out by Captain Anderson in a proof report on rockets fired at Shoeburyness.

[12] Vide (omitted).

[13] To be clear of the line as it runs out.

[14] The slide lid in Mark II machine over the opening on the right side used for the admission of a portfire is to be kept closed. Should the tube be found weak a few strands of quick-match may be doubled and inserted so as to project from the vent of the rocket.

time wasted, but, after the line becomes dirty and wet, the chances of success are decreased. At short ranges it may be desirable to fire the rocket at a lower elevation than 35°, for it is easier to project the rocket between the masts, when the line must, of course, follow it, than to fire it high in the air with the allowance necessary to cause the line to fall between the masts.[15] When the crew of the wreck signal that they have the line,[16] the rocket-brigade make fast their "whip" by bending the rocket-line round both returns at about 12 feet from the tailed-block and signal.[17] The wreck's crew then haul in and make fast the tail of the block *about* 18 *inches below the highest secure part of the ship*[18] (some distance up the mast, if possible),[19] unbend the rocket-line and signal. While the crew are drawing this "whip" in, it is especially necessary that the brigade on shore should see that the lines are carefully paid out to them, keeping the two parts steadily in hand at the same time, not letting them out faster than the crew on board the wreck can haul in; the men who have charge of the two coils of the whip being specially careful that the lines run out all clear from the coils. On seeing the ship's signal the brigade attach the hawser 6 or 9 feet from its end to one return of the whip and haul on the other return, so as to carry the hawser to the ship; which the crew make fast 18 inches above the whip (*i. e.* to the highest safe point), and then disconnect it from the whip and "signal." While those on shore are hauling the hawser on board the ship, it is especially necessary that the men in charge of the whip should keep the returns of the opposite end, if possible, 30 yards or more apart, and the hawser nearest to the hauling part, to prevent the hawser taking turns round the whip, which is very liable to occur even when these precautons are observed, and the wrecked crew should, if possible, ascertain before making the hawser fast that it is all clear. On this, the brigade having adjusted the block of the breeches buoy to run on the hawser, attach one return of the whip line to it by a clove hitch, and if the motion of the wreck is slight, lead the hawser through the snatch-block of the triangle, and set it up (*i. e.* haul it taut), by means of their "double block tackle purchase." This, however, can be paid out or hauled in but slowly, if required to follow the motion of the vessel. If, therefore, the sea beats the wreck about violently it will be better not to use the double block-tackle, but to keep the hawser taut by manning it with as many hands as can be spared, so as to follow the oscillating motion of the wreck without risk of the communication being broken.

It will be seen in the wood-cut that while the whip return by which the buoy is hauled towards shore must be pulled fair along the hawsers, the opposite return should throughout be kept wide of it.

The crew may descend one, two, or even three at a time, in the breeches buoy.[20] In cases of very violent wind the empty breeches buoy has been carried right round over the top of the hawser,[21] fouling the whip with it; it is therefore well not to let it pause while on a journey, especially when traveling empty back to the wreck.

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[15] Even at 35° I believe the rocket generally passes between masts.

[16] Either by a wave of hand or flag, a light shown, or a gun fired.

[17] Generally by red flag by day, and red light by night. *Vide* board of trade directons.

[18] There are many reasons for this. 1st. The hawser will bend with the weight of any person traveling on it, and perhaps let them into the water. 2d. If near the water the wash of the sea may twist and foul the ropes. 3d. The higher the starting point, the easier it is to haul a weight to the shore.

[19] I have been informed of an instance of a whole crew being drowned by making fast to the knightheads on the deck, instead of some point up the mast. I may observe that a brother of my own in traveling experimentally on a low hawser descended into the sea, but it is hardly necessary to enunciate that there is a limit to the distance which a person can be drawn through the surf without drowning.

[20] For the quickest rate, &c., see subsequent pages.

[21] Captain Robertson informs me that this has been reported as having occurred.

In urgent cases, such as the threatened immediate break up of the wreck, one or more buoys with lines to them communicating with the shore may be passed to the wreck directly the whip is made fast, or, again, the "buoy" may be made fast to one return of the endless line while it travels on the other,[22] at the same time the hawser should be set up when practicable.[23]

V. Flight of life-saving rocket.

It may be seen that the construction of the life-saving rocket is not such as will enable it to carry truly when fired without its rope. Its stick is fixed on one side of it, hence in flight the resultant of the resistance of the air on its anterior part, acting at a point termed by General Maievsky its "center of resistance," will not be opposite to its center of gravity, and hence a couple tending to deflect the rocket will be established. On page * * * the case of a rotating elongated projectile proceeding in a direction not coincident with that of its axis is discussed. The case of the rocket somewhat resembles it, the tendency of the rotation to resist the deflecting couple being answered by the mechanical action of the stick, * * * the velocity of rotation and the length of the stick being the relative "functions" of the steadying force in the two cases.

Now the stick of the life-saving rocket is not only placed on one side, but is also a little curtailed in its length; it may therefore be readily seen that this rocket is constructed on the supposition of its carrying a line, when the pull of the line from the starting point will act to draw the stick and rocket into the production of the line of flight it has taken up to the moment considered; this steadying power (in spite of the wind carrying the middle of the line in a bend to one side) becomes very great indeed after the rocket has proceeded any considerable distance. From this may be deduced two facts, which it may be vitally important to consider in firing the rocket:

1st. That the wind will carry the rocket and line with it, because it will not have the power to deflect its axis so as to point the rocket up the wind.

2d. It is very desirable to start the rocket at a momentary lull; for if the first action of the wind carries the rocket to one side, it will exert its force afterwards in prolongation of this incorrect direction.

If the rocket machine be brought into action on uneven ground, causing the foot on one side to be lower than that on the other, or if one foot sink deeper than the other, as might occur in yielding sand, the effect will be to cause the rocket to carry towards the lower side.

Issue: Six rockets in a packing-case.

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[22] The endless line must be cut to effect this; it is best to make fast the ends to the grummets or opposite sides of the life-buoy.

[23] Various methods of escape from a wreck have been devised and some carried out; the crew are generally in a nearly helpless condition with the waves beating over them, the most feasible expedient appears to me to be that of a kite, as there is generally a violent wind blowing from the wreck to the shore, and considering the comparative sizes of the ship and the land it seems reasonable (as proposed by Captain Nares, R. N., *vide* "Seamanship," by that officer, p. 220–22) to call attention to the possibility of the crew making and getting off a kite when the means on land were insufficient to establish a communication. Once let the kite fly over the land, the sudden paying out of its line would cause it to drop on the shore. Captain Robertson, R. N., informs me that a man has been known to swim from a ship with a line, assisting himself by a kite; it is here obvious that the kite might have carried a light line by which might have been passed stronger ones till a hawser was at last carried across.

VI. EXPERIENCE AS TO RANGE AND ACCURACY.[24]

In 1868, 52 rockets fired in succession, in course of proof, at 35° elevation, gave an average range of 378 yards, which may be considered a low one. It certainly includes one or two exceptionally short ranges.

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[24] The following are answers which were kindly furnished by Mr. J. F. Spence, honorary secretary to the Tynemouth Life Brigade, to some of my questions. I think most readers would prefer having such answers *verbatim* to any summary, which would destroy their character and the spirit which runs through them. It would be difficult to quote a better authority than Mr. Spence in these matters.

The quickest successful performance of work you remember?

"This was with the schooner Light of the Harem, wrecked behind Tynemouth North Pier on the 8th of February last (1870). The rocket was fired at 30 minutes past 4 p. m., and the first man was landed in 14 minutes; the last man (there were five of them) in 24 minutes from firing the rocket. That was nearly 5 minutes a man. This would have been much more quickly done, but the men on board the schooner did not understand how to use the apparatus, and so delayed many minutes. You will notice the four last men were landed in 10 minutes (the first man occupied 14 minutes); but, as I said, this arose in a measure from their ignorance of how to act."

1. *As to kinking of manila lines, &c.*

"The rocket lines are now made of hemp (at least, so we suppose), and are much more softly laid than they used to be. The result is, they rarely kink. We still have the old trouble with the lines fouling as they are drawn off; that is, when the whip is on board and made fast. You then attach the hawser, leaving about two or three fathoms free, in order that the wrecked people may more easily fix it to the mast. This free end is very liable to take turns round the whip in hauling off, and the result is and often has been that the breeches buoy cannot be hauled off to the ship. In daylight, if this happens, any sailor sees it at once, and can put it right, but in a dark, stormy night this is much more difficult to do, and when they think they are taking the turns out they may be making more. It also necessitates slacking off the hawser, so that the people on board ship may loose it to get the turns out."

2. *The greatest range you have reached.*

"I presume you will mean when firing at a ship in distress. On the 8th of February, 1870, at 3.30 p. m., a large bark was stranded on the Spar Hawk, a spit of sand about half a mile east of the Black Midden Rocks, at the mouth of the Tyne; she would be about 350 or 360 yards, at least 350 yards by *measurement*, from the nearest point of the rocks on which we could stand to use the apparatus. The first shot fell far short of her, we suppose because it had not sufficient elevation, and the line was wet. The second rocket was laid with a few degrees more elevation, with a new rocket line quite dry and fresh, and flew right between her masts. The line is 250 fathoms in length. I think there might be 10 or 12 fathoms of the line left in hand. The wind was S. E. by S., force 10, blowing almost athwart the line. This was a grand shot; I never saw a better. No one thought the vessel could be reached."

3. *Whether you generally lose one or more rockets before you establish a communication?*

"The force of wind, and position in which the ship lies with respect to the direction of the wind and situation of those on shore who are endeavoring to establish a communication, greatly affects this question; for instance, there may be a sudden lull in the violence of the wind, and you think to take advantage of it, lay your rocket accordingly, and fire; just as you pull the trigger line, the squall returns with renewed force, and the consequence is, your rocket is carried far away from the object aimed at. In most instances, however, we have succeeded in throwing the line over wrecked ships the first shot; I think we only missed once—in the case I have detailed to you. Then comes another difficulty; take an instance. On the 8th of February, this year, at 4 o'clock a. m., the 'Susannah,' a schooner, was wrecked on the Black Midden Rocks, wind S. E., force 10. It was about 500 yards from the station to the point of rocks, the nearest we could reach to her. In 22 minutes we fired the first rocket, which went right over her, but there was no attempt to pull the line on board; we went on firing rockets till five in all were expended. The lines all fell over the vessel, but it turned out that the rigging was in such a wretched state that the men could not disentangle one of them from it till the last one was fired, which went clear. In 10 minutes from this time we had the first man ashore, and in 12 minutes more the other three, but they were very much exhausted, as it was nearly 7 o'clock a. m. when we got them. For two hours and a half they had been exposed to the full fury of the storm, every wave rolling over them; one man was lost—washed overboard with one of the masts."

4. *Do you find the system of work so far understood generally as to enable the crew to conform to your operations?*

"In many cases I say they do not; this is one of the difficulties we have to contend

the minimum one being 286 yards, the maximum 450. The average deviation from the line on which the rocket was laid was 42 yards.

In 1870, 131 rockets fired successively at proof gave an average range of 373 yards, the maximum range being 470 and the minimum 330, the mean deviation being about 35 yards.

In calculating for the effects in cases of storm, rather a low range must commonly be expected, the wind generally blowing more or less against the direction which the rocket has to take.

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with on a dark night, and with a ship at such a distance from the shore that we cannot make the crew hear. I have urged strongly on the board of trade to have a clause in the new merchant shipping bill, making it compulsory on all owners of seagoing vessels of all descriptions to have their simple directions as to know how to use the apparatus painted on a piece of tin, and nailed to the mast or in some conspicuous part of the vessel, so that the sailors cannot help learning what they have to do when wrecked and a rocket or shot is fired over them. I never knew a crew to establish communication with a kite, but have heard of its being tried. I fear in case of shipwreck it would be difficult to set a kite up."

The following accounts, taken from the annual report of the Volunteer Life Brigade of the borough of Tynemouth, will enable any officer to realize the kind of difficulties likely to occur in the actual course of work:

"As was noticed in last annual report, but few southwest gales of any length of continuance or severity have occurred since the year 1864, when the steamship Stanley was wrecked; but, as might be expected on the occurrence of severe gales from that quarter, during the past winter, several wrecks took place at the north side of the mouth of the Tyne, and it was during one of these gales that the brigade had the great satisfaction and privilege of landing the crews of two vessels, with the exception of one man who was washed overboard with one of the masts which was carried away by the force of the waves. In the case of the Susannah, which was stranded about four o'clock in the morning of the 8th February, 1870, it seemed at times as though there was little hope of saving the crew. She was so much disabled in her masts and rigging before drifting ashore, and had so much wreckage hanging about her, that rocket after rocket was fired (five in all) before any practical communication could be effected with the ship, and the rocket lines becoming so entangled in the rigging that the men on board could not clear them. Finally, however, after two and a half hours working and waiting, the persistent efforts of the coast guard and the brigade were crowned with success. It was during the continuance of this storm, about 3.30 in the afternoon of the same day, that the bark Helena, of Scarborough, with a crew of 17 hands and the pilot, came ashore in a violent snow-squall, on the edge of the Spar Hawk; she was at a considerable distance from the nearest point where the apparatus could be set up, and there seemed some doubt about reaching her with a rocket. The first shot fell far short, but the second rocket went right between her masts, and was secured by one of the men; the life-boat, however, coming alongside soon after, the crew very wisely took to her rather than run the risk of being dragged through the surf and over the rocks amidst the raging sea, which must of necessity have been a very hazardous operation. Whilst this was on the way, the cry was raised that another vessel was going behind the North Pier, a most dangerous position; the chief officer of the coast guard, Mr. Quick, immediately told off some of the volunteers, with one or two of the coast guard, to go to her assistance. In a short space of time they had the satisfaction of landing the whole of the crew, though not a moment too soon, as about eight minutes after they were ashore the schooner was broken up by the fury of the storm, not a piece of her being left on which they could have saved themselves. She proved to be the schooner Light of the Harem, of Lowestoft.

In the case of the Burton, of Wivenhoe, wrecked on the 19th of March, 1865, a rocket line was thrown over her in two minutes from the time she touched the rubble of the North Pier, but in seven minutes she went entirely to pieces, the poor fellow who climbed the rigging to lay hold of the rocket line not having time even to reach it. Only one man was saved out of the crew of five; he was picked up by the life-boat.

Again, on the evening of the 11th October, 1865, about 7 p. m., the schooner Ringwood, of Yarmouth, with a crew of five hands, when endeavoring to enter the harbor, in a stiff southeast gale, came ashore on the Black Middens. The rocket line was speedily over her and the whip attached but was not hauled aboard. It was soon found that the men, who were used to the Yarmouth beach, had left the vessel in their boat, which unfortunately capsized, and two of them were drowned; had they remained on board and used the apparatus, there is little doubt they would all have been saved. On the third occasion, the 29th December, 1865, three vessels came ashore under the battery; rockets were fired over two of them, but the men did not seem to understand the use of the apparatus, *and instead of hauling the line aboard, fastened a warp to it, and commenced paying out toward the shore.* In the mean time the life-boat came alongside and saved the whole of the crews."

The following is a return of the number of rockets fired at each drill of the Borough of Tynemouth Life Brigade, from 1st July, 1866, together with the range in yards as near as could be ascertained; the deviation right or left of the rocket of the object aimed at; the time, in minutes and seconds, between firing the first rocket and landing the first man, and the number of men present on each occasion; compiled for the board of trade returns by John F. Spence, honorary secretary. Previous to 1866 no record of these particulars was kept.

Date of drill.	Number present.	Rockets fired.	Range, in yards.	Deviation right or left, in yards.	Time from firing to landing of first man, in minutes and seconds.	Remarks.
July 28, 1866	56	1	Always fired from the same position and varied from 240 to 300 yards.	7 to left	Varied from 9½ to 15 minutes. The object aimed at varied from 180 to 240 yards distance.	
Aug. 25, 1866	47	1		2 to right		
Sept. 22, 1866	47	2		1 nowhere; 1 hit		Rocket frame upset and rocket flew off.
Oct. 26, 1866	39	1		4 to left		
Nov. 29, 1866	42	1		Hit		
Dec. 22, 1866	44	1		2 to left		
Jan. 19, 1867	46	1		1 to left		
Feb. 16, 1867	53	1		Hit		
Mar. 13, 1867	59	1		Hit		
Apr. 12, 1867	35	1		4 to right		
May 11, 1867	29	1		2 to right		
June 14, 1867	39	1		Hit		End of official year.
July 12, 1867	46	1	About 230	Hit	14 00	
Aug. 9, 1867	41	1	About 290	Hit	8 30	
Sept. 6, 1867	44	2	Ab't 340; Ab't 290	Hit	15 45	First shot all the line carried away, being an old short one.
Oct. 4, 1867	75	1	About 280	Hit	7 40	
Nov. 2, 1867	60	1	About 280	4 to right	8 45	
Nov. 30, 1867	51	1	About 285	10 to left	20 00	Lines fouled in rocks, a member waded in to free them.
Dec. 28, 1867	38	1	About 250	Hit	15 00	
Jan. 25, 1868	72	3	About 200	30 to leeward; 10 to leeward; Hit	11 00	Rocket stand fell twice into the sea.
Feb. 22, 1868	67	1	About 210	5 to left	12 00	
Mar. 21, 1868	50	1	About 260	Hit	15 30	
Apr. 18, 1868	41	1	About 280	2 to right	12 15	
May 15, 1868	42	1	About 270	Hit	10 30	
May 29, 1868	64	1	About 280	4 to left	9 40	
June 26, 1868	44	1	About 265	Hit	7 30	
July 24, 1868	45	1	About 280	Hit	12 30	
Aug. 21, 1868	55	2	About 270	3 to left	14 00	
Sept. 19, 1868	46	1	About 260	4 to right	16 00	
Oct. 17, 1868	30	1	About 320	3 to right	15 00	
Nov. 14, 1868	38	1	About 330	10 to left	11 00	
Dec. 12, 1868	51	1	About 280	Hit	12 00	
Jan. 9, 1869	49	2	260; 250	4 to right; Hit	10 30; 17 00	Trials of new iron triangle double and single apparatus.
Jan. 29, 1869	60	1	320	Doubtful	19 00	
Feb. 10, 1869	36	....	....	....	....	No account kept as there was no opportunity of doing so.
Feb. 11, 1869	36	....				
Mar. 6, 1869	38	1	About 330	Hit	17 00	
Mar. 31, 1869	34	1	About 300	Hit	(*)	No time kept, as the drill was constantly stopped to make explanations to the American Ambassador.
Apr. 30, 1869	58	1	About 280	3 to left	....	
May 28, 1869	52	1	About 320	Hit	12 00	
June 25, 1869	37	1	About 250	1 to left	6 00	
Aug. 6, 1869	40	1	About 280	2 to left	20 00	
Sept. 3, 1869	50	1	About 340	Hit	13 30	
Oct. 2, 1869	34	1	About 190	12 to left	11 00	
Oct. 30, 1869	48	1	About 300	10 to right	12 00	
Nov. 27, 1869	42	2	About 340	Miss, 10 to left	19 00	
Dec. 23, 1869	37	1	About 320	Hit	18 30	
Jan. 22, 1870	43	1	About 310	Hit	12 00	
Mar. 19, 1870	66	1	About 290	Hit	17 00	
Apr. 14, 1870	48	1	About 300	12 to left	19 00	
Apr. 23, 1870	79	1	About 220	4 to left	12 30	
May 20, 1870	45	2	About 290	3 to left	12 00	One fired to sea without a line.
June 24, 1870	35	1	About 300	Hit	14 00	

*American Ambassador Hodgson's storm escape.

VII. The keeping qualities of rockets.

The keeping qualities of rockets are not satisfactory. They should be stored in as dry a place as possible.

Mr. Abel, chemist, W. D., gives his opinion as follows:

The corrosion of the metal at the seam of the case has not been set on foot in the first instance by the borax employed in brazing, as no trace of the existence of borax can be detected upon the metal at the joint. The saline matter scraped from the exterior of the case contained carbonate of potash. The deliquescent and alkaline nature of this salt accounts for the collection of moisture on the case and for the destruction of the paint coating.

This carbonate of potash is a product of the decomposition of the saltpeter from the rocket composition, and it is owing to some imperfection in the brazing that small quantities of saltpeter have been admitted in the operations of pressing that a corrosive action has been established which has been promoted by gradual access of air and moisture to those points, and by the coexistence of brass and iron in contact with the composition.

The action of the saltpeter upon the metal appears to have spread in the interior of the case round that part where the brazing extends to a very slight degree, but sufficient to effect a separation between the composition and the case, which are found to be very firmly attached to each other at all other parts of the case.

The slight symptoms of corrosion round the rivets at the head of the rocket are evidently due to the penetration of minute quantities of saltpeter (forced in by pressure) applied in manufacture to the exterior between the rivets and the holes; the non-existence of brazing at these points renders the action very trifling.

The employment of brazing in the closing of the rocket cases is evidently a cause of deterioration; the existence of minute imperfections in the joint made by brazing is probably unavoidable, and as the saltpeter must penetrate on pressure, the establishment of corrosion is unavoidable.

VIII. Contents of cart.

1. Two or three *rocket lines* laid up loose; one end of the rocket line is to be attached to and launched with the rocket.
2. Boxes fitted with faking-pins, in which to stow the rocket lines.
3. A *hawser* of 3-inch Manilla right-handed rope, from 40 to 120 fathoms, according to the steepness or flatness of the shore.
4. A "whip" of Manilla line, not exceeding 1½ inches, rove through a single tail block. The "whip" to be made of left-handed rope, the reverse of the hawser, and the tail of the block to be at least two fathoms in length, and the sheave to be brass-bushed. The ends of the "whip" to be spliced together, so as to convert it into an endless rope.
5. A *sling life buoy*, with petticoat breeches, in which to place the person to be rescued, and haul him ashore.
6. A *traveler*, or inverted block, with a brass sheave, to be attached to the "sling" and carry it along the "hawser."
7. A "double block tackle purchase," for setting taut the "hawser," one of the blocks being fitted with two tails to bend on to the hawser, or with luff-tackles fitted to put on to the hawser with strop and toggle (like a top-gallant or royal purchase). The blocks to be brass-bushed.
8. Three small *spars* to form a triangle, over which the hawser may be passed and thereby raised higher above the water. This will be found convenient on parts of the coast where the shore is flat. The triangle should be fitted with a swivel snatch-block, brass-bushed, instead of standing hooks; the strapping of the block to be of good iron.
9. An *anchor* with one fluke to be buried in the earth, sand, or shingle, to which to set up the hawser by means of the tackle-purchase. Or, in some places where the shore is composed of soft shingle or sand, and where an anchor will not hold, a stout plank, 5 or 6 feet long, with a fathom of chain of sufficient strength fastened around it amidships, may be substituted for the anchor. This plank being buried 3 or 4 feet be-

neath the ground, and the end of the chain, with a ring attached, led to the surface, the hawser may be set up to it by the tackle-purchase in the same manner as to an anchor.

10. A *red flag*, 2 feet by 3 feet, fixed at the end of a staff 5 feet long, and a lantern with a *red* lens fixed in it, to be used as signals in the manner directed below.

11. Two or three *spades* or *shovels*, and a *pickaxe*, to be of good quality, and suitable for the work; *a salvagee strop*, a few pieces of *extra rope*, to be used as occasion may require.

12. A light *hand-barrow*, when thought necessary, for carrying portions of the apparatus from the cart to the place where it is to be used.

13. Three sets of *tally-boards*, each set consisting of two boards of hard wood about 9 inches long by 5 inches wide and ¾ inch thick. These boards to have the following words painted on them in white letters on a black ground, English on one side and French on the other, viz:

No. 1 tally-board to be attached to the whip.

English: Make the tail of the block fast to the lower mast, well up. If the masts are gone, then to the best place you can find. Cast off rocket line; see that the rope in the block runs free, and show signal to the shore.

French: Fouettez la poulie le plus haut possible sur le bas-mât, ou à l'endroit le plus favorable si les bas-mâts sont perdus. Detachez la ligne, voyez que la corde coure facilement dans la poulie, et faites signal au rivage.

No. 2 tally-board to be attached to the hawser.

English: Make this hawser fast about 2 feet above the tail-block. See all clear, and that the rope in the block runs free, and show signal to the shore.

French: Amarrez cette aussière à deux pieds environ au dessus de la poulie. Voyez que rien n'engage et que la corde coure facilement dans la poulie, puis faites signal au rivage.

14. *Long light.*—One box of Colonel Boxer's, to be used as occasion may require.

15. *Signal rockets.*—Eighteen, throwing white and red stars.

16. *Two heaving sticks* and lines, to be used as occasion may require.

17. *A water barrico*, with a large square hinge-bung, large enough to admit a man's hand, will be supplied if specially demanded.

18. *A hawser-cutter*, for the purpose of severing a hawser from a wreck.

19. *A tarpaulin*, to cover over the apparatus and stores in the cart when the apparatus is not in use, and fitted with beckets and tent pegs to secure it on the beach or shore for coiling the whip on when the apparatus is in use.

20. *Life-belts.*—Two of Captain Ward's, and two life-lines.

N. B.—The whole of the gear, and a sufficient supply of rockets, &c., are to be kept in the rocket-apparatus cart, *in good order, dry, and ready for immediate use.*

IX. Rocket apparatus drill.[1]

1. *Always keep the gear dry and well aired.*

2. Upon the approach of a storm or thick dangerous weather on the coast, muster the gear and small stores, examine the cart, especially the axletrees, trim the lamps, and prepare for service.

3. On a wreck occurring, the watchman will call the officer and men, and send for the horses.

[1] Issued by the Board of Trade [English] June, 1875.

4. Great care should be taken in arranging the apparatus with precision for firing, as after the lines become wet or dirty there is less chance of effecting a communication.

5. The rocket-line should be fastened to the rocket-stick as shown in one of the engravings. The line should have about three fathoms wetted before being rove, and should also have a figure of 8 knot made near the hole at the end of the stick, so that if the line is burnt near the rocket the knot will prevent it getting free.

6. The first rocket should always be fired with the line in the box, and the box should be slightly tilted towards the wreck.

7. In hauling off the hawser *do not stop the end up with a rope-yarn, but leave three fathoms hanging loose.*

8. When working the whip keep the veering part well separated from the hauling part, the parties at each standing as far apart as possible, the hawser being between the two. Lift the whip well in order to keep clear of surf or sea-weed.

9. When the service or exercise is over, the stores are to be returned to the cart and the party to fall into the "order of march," and return to the station.

10. *Great care should always be taken that the whole of the gear is thoroughly dried before being put away. All kinks and turns should be carefully taken out of the lines and whip.*

DRILL.

Words of command.

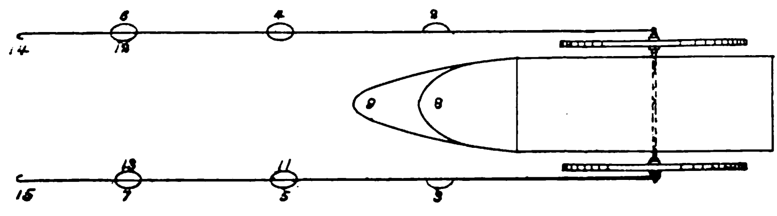
1. Rocket party fall in.
2. Form the order of march (or double).
3. Halt.
4. Action.
5. Ready.
6. Fire.
7. Haul out.
8. Haul ashore.

1. *Rocket party fall in.*

2, 4, 6, 8, 10, 12, 14, rear rank.
1, 3, 5, 7, 9, 11, 13, 15, front rank.

Rocket Nos., 1, 2, 3, 4, 5, 6.
Auxiliaries, 7, 8, 9, 10, 11, 12, 13, 14, 15.

2. *Form the order of march.*



Duties at the order "Halt," "Action."

No. 1 places rocket-frame; pins rocket to staff; inserts fuse; places rocket in frame; reeves line through staff; makes a figure of 8 knot near

the heel of staff; puts on two India-rubber and one metal washers, and then makes another figure of 8 knot in the end of the line-points; elevates (making due allowance for force and direction of wind); applies portfire to time-fuse, and then steps clear and removes frame when communication is effected.

No. 2 assists No. 3 to place box with line 6 yards to the rear of frame; lifts box clear of pins; fakes the stray rocket-line to the rear of frame; bends rocket-line to whip, and then takes charge of right side of whip.

No. 3, assisted by No. 2, places box with line 6 yards to the rear of frame; lifts box clear of pins and cants it in the direction of the wreck, and at right angles to the line of fire; takes out water barrico and wets about 3 fathoms of end of line; then hands it to No. 1, assisting him to reeve it, and takes charge of the left side of whip.

No. 4, assisted by even numbers of auxiliaries, carries the whip 8 yards to the rear of frame, sees it clear for running, and then bends it on to hawser[1] about 2 fathoms from the end.

No. 5, assisted by odd numbers of auxiliaries, takes end of hawser and tally to 4, and clears it away for hauling off to the wrecks; clove hitches whip to traveler; bends on breeches buoy; raises triangle, and snatches hawser.

No. 6, assisted by even numbers of auxiliaries, buries anchor and backer, hooks on luff to anchor, and secures it to hawser.

No. 7 attends signals under direction of officer.

NOTE.—If there is no 7, officer attends signals.

No. 8 takes charge of life-belts, and attends to stranded crew when landed.

Odd numbers assist No. 5 to clear away hawser, keeping a slight strain on it while being hauled off to wreck; even numbers assist No. 6 to bury anchor and backer, &c., and then man the fall of the luff-tackle purchase, and veer and haul as necessary.

Even numbers assist No. 4 in working the whip, hauling off hawser, &c.

NOTE.—In working the apparatus with only six men, 3 and 5 assist No. 6 to raise triangle and attend hawser; 1, 2, and 4 attend and work the whip.

Auxiliaries.—All auxiliaries are to assist in carrying stores from cart to point of action.

Even numbers haul out hawser and breeches buoy.

Odd numbers haul ashore.

All numbers above 15 should be told off to guard the ground.

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[1] Tallies are always to be kept bent on both hawser and whip, so as to be ready for service.

APPENDIX P 1.

REPORT OF C. B. RICHARDS, ENGINEER OF COLT'S PATENT FIRE-ARMS COMPANY, UPON TESTS OF THE BEHAVIOR UNDER TENSILE STRESS OF SPECIMENS OF BRONZE RECEIVED FROM LIEUT. D. A. LYLE, ORDNANCE DEPARTMENT, UNITED STATES ARMY, WITH A DESCRIPTION OF THE TESTING-MACHINE USED.

(Plates XLII–XLV.)

The statement of the results of the tests is prefaced by descriptions of the testing-machine and apparatus used and the methods employed in the experiments.

The testing-machine is one which has been in use in the armory of this company since 1871. The basis of the machine is a platform-scale, by which the forces applied to the specimens are weighed with the same accuracy that any load may be weighed by similar scales.

Figures 1 to 4 in the accompanying drawings show different views of the machine: figure 1 being a rear elevation and figure 2 an end elevation of the entire machine; figure 3, a front elevation of the weigh-beam apparatus, and figure 4 an elevation, partly in section, of certain parts of the strain-indicating apparatus, drawn on a larger scale than the other elevations.

A is the platform of a 50-ton scale, of which B is the weigh-beam, with its sliding weight, C. Upon the platform a cast-iron frame, D, is placed, to sustain the nut of a screw, E, to whose lower end are applied the fixtures for holding the upper end of a specimen intended to receive a tensile strain. The platform is 5 feet long by 3 feet wide, and has an oblong opening in its center, through which two long screws rise about 2 feet above the platform. The screws carry a strong cross-head, F, which can be raised or lowered by two nuts, G. The screws and cross-head are not connected with the platform until the specimen makes the connection. The crosshead receives the fixtures for applying strains of all kinds to specimens of every shape. For tensile strains the holders which grasp the lower end of the specimen are attached to the top of the cross-head. The lower ends of the screws G are attached to the short arms of a massive forked lever, H, which is beneath the floor, and has its fulcra supported by the bed-plate which forms the foundation of the scale. The long arm of this lever is coupled to the fulcrum *i* of a short lever, I, which is so suspended from a longer lever, J, that the two levers form a differential system, the fulcra *j* and *i* of the two levers not being in the same vertical plane. The fulcrum *j* of lever J is raised or lowered by a screw, K, whose nut is supported by a cast-iron frame, L, erected upon the scale-foundation. This nut is worked by the hand-wheel M through a system of toothed wheels, or, when the back gearing (shown at N, Fig. 2) is thrown into engagement by turning the lever N′, the nut may be worked through the pulley O by power obtained from the factory shafting. The connections between the lever J and the screws G, which carry the cross-head, are so arranged that, by depressing the longer free arm of J the cross-head is pulled downward, and by raising the fulcrum of J the same result is produced. A rod, P, is suspended from the end of the longer arm of the lever J, to which plates and pans are attached to receive weights of various values, and counter-weights Q may be applied to the shorter arm of the lever to balance wholly or partly the preponderance of the longer arm. The lower end of the rod P is provided with a piston, which moves in a large

cylindrical vessel containing oil and serving to prevent a too rapid fall of the loaded end of the lever. If the foregoing description is understood, it is evident that if one end of a specimen, a rod of iron, for instance, be attached to the frame D above the cross-head F and the other end be attached to the cross-head, the specimen may be stretched by bearing down the end of the straining-lever J, for the cross-head will thereby be pulled downward. The arms of the levers are so proportioned that one pound applied at P will exert a strain of 120 pounds on the specimen: so a strain of 100,000 pounds will be exerted by the application of 800 pounds at P. The specimen can also be strained by weighting the rod P so heavily that it will be held down, and then by working the nut of the screw K, either by hand or power, the fulcrum *j* will be raised, and the cross-head pulled downward with a force increasing as gradually as may be desired. As the specimen is suspended from the frame on the platform of the scale, any stress with which it is pulled will be indicated at the weight-beam B and can thus be accurately weighed. The strain-indicating apparatus is shown in Figs. 3 and 4. B is the weigh-beam of the scale with its sliding-weights C. The beam is graduated to thousand-pound intervals, and the small weight will show 20-pound increments. A long straight rod, *a*, hangs at the end of the weigh-beam and dips into a cylindrical vessel, *b*, which is movable up and down and is filled with mercury. The weight of the rod *a* is so adjusted that when the rod hangs wholly in air it will exactly balance 10,000 pounds on the platform of the scale, but when immersed to a certain point in mercury it floats and ceases to act as a weight; between these two points its value as a weight depends on the extent of its immersion in the mercury, which is regulated by the height at which the vessel *b* stands. The mercury vessel may be raised by turning a pinion which works in a rack fastened along the side of the vessel and the vessel may be held up by a pawl, *c*, which tends to engage with the teeth of a ratchet-wheel, *d*, fastened to the pinion-shaft. When the pawl is disengaged and its from the wheel, the vessel descends by its own weight, but its speed of falling is controlled by a piston sliding in a cylinder, *e*, filled with oil, the top of the piston-rod *f* being connected with the vessel by a chain passing over sheaves *g*. A pipe, *h*, connects the upper part of the oil-cylinder with the lower part, and a screw-valve, *k*, in the pipe regulates the flow of oil which is produced by the piston rising through the cylinder. The variation which opening or closing the screw-valve *k* occasions in the resistance to the flow of oil through the pipe affords the means of regulating the rapidity of descent of the vessel *b*. A valve in the piston permits the mercury vessel to be raised quickly, even when the screw-valve *k* is closed. A scale, *l*, on the side of the mercury vessel indicates the extent to which the rod *a* is immersed in the mercury, and the scale is so marked that the valve of the rod in balancing a load on the platform may be read for any position of the vessel to within 20 pounds, which is as small difference as the testing-machine is intended to indicate. The range of the scale is 10,000 pounds. The values of the scale readings can be checked at any time by the weights C on the beam, and have been found to be invariably correct. When greater loads than 10,000 pounds are to be observed the surplus is balanced at the beam by the weights C. When used to weigh gradually-increasing strains, the operation of this apparatus is made automatic in the following manner:

On the end of the weigh-beam B is fastened a small cup, *m*, containing mercury, into which platinum wire, *n*, constantly dips. The point of a second platinum wire, *p*, stands a little above the surface of the mer-

cury when the beam B is down, but when the beam rises this wire also dips into the mercury. The platinum wires form the terminals of two insulated wires leading from the two poles of a galvanic battery whose circuit is closed when the rising of the beam immerses the two platinum points in the mercury, but is open when the beam is down. An electro-magnet, *r*, is inserted in the course of one of the wires and the armature of this magnet is so connected with the pawl which sustains the mercury vessel that when the battery circuit is closed and the magnet is thus vitalized, the pawl *c* is drawn away from the wheel *d*, but when the circuit is broken the pawl falls back again and locks the wheel.

When sufficient stress to overcome the weight C is applied to a specimen the weigh-beam rises and closes the electric circuit by which the pawl is made to unlock the wheel *d;* the mercury vessel then descends until enough of the rod *a* is uncovered by the mercury to enable the rod to balance the stress and draw the beam downward. The electric circuit is thus broken, and the pawl locks the wheel, preventing a further descent of the mercury vessel and leaving the beam poised until it is raised by a further increase of stress.

This automatic action may be continued until the specimen breaks, when the beam of course drops and the mercury vessel *b* is locked in place by the pawl. The sum of the readings of the weight C on the beam, and the scale *l* on the mercury vessel, gives the maximum stress on the specimen.

Figures 5, 6, and 7 show one of the pair of clasps for fastening the specimens in the machine. Figure 13 represents the finished specimen, and figure 12 shows the specimen with nuts screwed on its ends to form heads by which the specimen may be grasped by the clasp. The clasp is made in halves hinged together, and is shown open in figures 5 and 6 and closed in figures 7 and 8. One clasp embraces the upper head of the specimen and the lower end of the screw E of the testing-machine, thus attaching the specimen to the screw. The other clasp embraces the lower head of the specimen and the upper end of a bolt fastened in the top of the pulling cross-head F, attaching the specimen to the cross-head and thus forming the connection between the cross-head and the platform. The halves of the clasps, when they are put in place in the machine, are locked together by pins passing through the axes of the hinges, as shown. A specimen is represented in place in the machine at *s*, figure 2. Two different gauges were used to measure the extensions of the specimens; one of these, shown in figures 11 and 12, was used for stresses within the elastic limit, and the other, illustrated in figure 9, was applied after the elastic limit was passed.

The first (A) consists of two plates of glass held face to face in separate steel frames, which are locked together and slide freely along each other; one of the frames is terminated by a ball, and the other by a stem, at the end of which is a similar ball. By grasping the balls and pulling them apart the glass plates slide along each other. On the longer glass plate a scale is ruled with fine lines, 1 inch being there divided into 100 parts. On the shorter plate a space $\frac{1}{100}$ of an inch long is divided into ten parts, the lines being $\frac{1}{1000}$ of an inch apart. The ball-shaped ends of this sliding gauge are clamped in the jaws of two holders, shown in figures 10 and 12, one of which is clamped around each end of the cylindrical part of the specimen. When the gauge is thus fastened in place and the specimen is stretched, the scales pass over each other lengthwise, and by observing the scales through a powerful microscope the extensions may be read to within a ten thousandth of an inch, for it is easy to subdivide to tenths by the eye the spaces between the lines of the small scale.

A microscope, not shown in the drawings, is so fastened on the machine that the gauge-readings can easily be observed.

The gauge B is a sliding vernier gauge, reading to thousandths of an inch. Its two ends are fastened to the two specimen clasps, which, as they become separated by the stretching of the specimen, draw the vernier of the gauge over the scale, and the extensions may be obtained from the changes in the gauge-readings.

Method of testing.

The specimens were tested in lots of 4 as they were received. Each one was first tested up to and somewhat beyond the elastic limit, the stress being applied by working the straining-screw nut by hand. The gauge A was applied to the specimen, and the extensions corresponding to different stresses were read from this by using the microscope. A reading was taken at 1,000 pounds, after which the stress was increased to 2,000 pounds, and a second reading recorded. The stress was then reduced to 1,000 pounds and the corresponding reading again taken. The extension at 3,000 pounds was then observed, and afterward at 1,000 pounds, and so on with increased stresses and repeated reductions of the stress to 1,000 pounds until the probable elastic limit was approached, when the increments of stress between the observations of extension were reduced to 500 pounds. As soon as a permanent set occurred, which indicated that the elastic limit had been exceeded, this was shown by a difference between the last reading at 1,000 pounds stress and former readings for that stress. The greatest stress observed before this set occurred has been taken for the elastic limit of the specimen. After the elastic limit had been exceeded by several thousands of pounds and the corresponding extensions observed for all the specimens, the first specimen was again placed in the machine and the gauge applied to the holders. A gradually increasing pull, starting from the greatest stress before observed, was then produced by working the straining-screw nut at a uniform speed by the pulley *o*, driven by the factory shafting, while the progress of the increasing stress was observed by watching the descent of the mercury vessel *b*, and at the instant the scale on the vessel indicated each increase of 1,000 pounds stress the reading of the gauge which indicated the corresponding extension was taken until the fracture of the specimen occurred. The extensions of the specimen by strain corresponding to the different pulling stresses were then plotted graphically, and the curves thus formed are shown in figures 14, 15 and, 16. Figure 17 is a photograph showing the original shape and surface of the specimen compared with its appearance after having been broken. The broken specimen here represented is No. 914, marked H3, from gun A.

The data and results of the tests are given in the accompanying table.

Report of the results of tests by the Colt's Patent Fire-Arms Manufacturing Company of the behavior under pulling stress of twelve specimens of bronze received from Lieut. D. A. Lyle.

[Dimensions and areas are given in inches, stresses in pounds, and resistances in pounds per square inch of the original cross-section of the specimen.]

Test number of the specimen	912	913	914	915	937	938	939	940	982	983	984	985
Original mark	A. H. 1.	A. H. 2.	A. H. 3.	A. H. 4.	B. H. 1.	B. H. 2.	B. H. 3.	B. H. 4.	C. H. 1.	C. H. 2.	C. H. 3.	C. H. 4.
Diameter of minimum cross-section. Original	0.789	0.797	0.797	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798
Diameter of minimum cross-section. After fracture	0.6.	0.61	0.6	0.73	0.66	0.67	0.665	0.73	0.74	0.75	0.73	0.75
Area of minimum cross-section. Original	0.498	0.499	0.499	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Area of minimum cross-section. After fracture	0.28	0.29	0.28	0.42	0.34	0.35	0.35	0.42	0.43	0.44	0.42	0.44
Distance between gauge marks. Original	3.49	3.49	3.49	3.49	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Distance between gauge marks. At instant of fracture	5.38	5.30	5.38	3.95	4.69	5.02	4.95	4.07	4.1	3.96	4.1	3.7
Distance between the shoulders. Original	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Distance between the shoulders. At instant of fracture	6.58	6.58	6.65	5.04	5.86	6.31	6.21	5.21	5.19	5.11	5.14	4.74
Extensions produced by increasing the stress from 1,000 pounds to 3,000 pounds	0.0011	0.0010	0.00085	0.0010	0.0011	0.0011	0.0011	0.0014	0.0014	0.0014	0.0014	0.0017
Greatest observed stress sustained without set	5,500	6,000	6,000	3,500	6,000	5,500	6,500	4,500	5,000	4,500	4,500	3,000
Breaking stress	23,280	23,340	23,740	14,220	20,820	21,900	21,920	16,860	13,980	13,200	13,980	9,580
Modulii of elasticity, in pounds per square inch	12,700,000	14,000,000	16,500,000	14,000,000	12,700,000	12,700,000	12,700,000	10,000,000	10,000,000	10,000,000	10,000,000	8,200,000
Limit of elastic resistance	11,000	12,000	12,000	7,000	12,000	11,000	13,000	9,000	10,000	9,000	9,000	6,000
Ultimate resistance (tenacity)	47,600	46,780	47,580	28,440	41,640	43,800	43,840	33,720	27,960	26,400	27,960	19,160
Greatest reduction of cross-section, per cent	42.1	41.5	43.3	16.4	31.6	29.6	30.6	16.4	14.0	12.	16.	12.
Ultimate elongation between gauge marks, per cent	54.1	51.6	53.9	13.3	34.0	43.4	41.4	16.3	17.1	13.1	17.1	5.7
Work performed in breaking the specimens, per cubic inch of material between the shoulders	1,500	1,700	1,500	*230	820	1,180	1,120	*370	280	230	270	*70

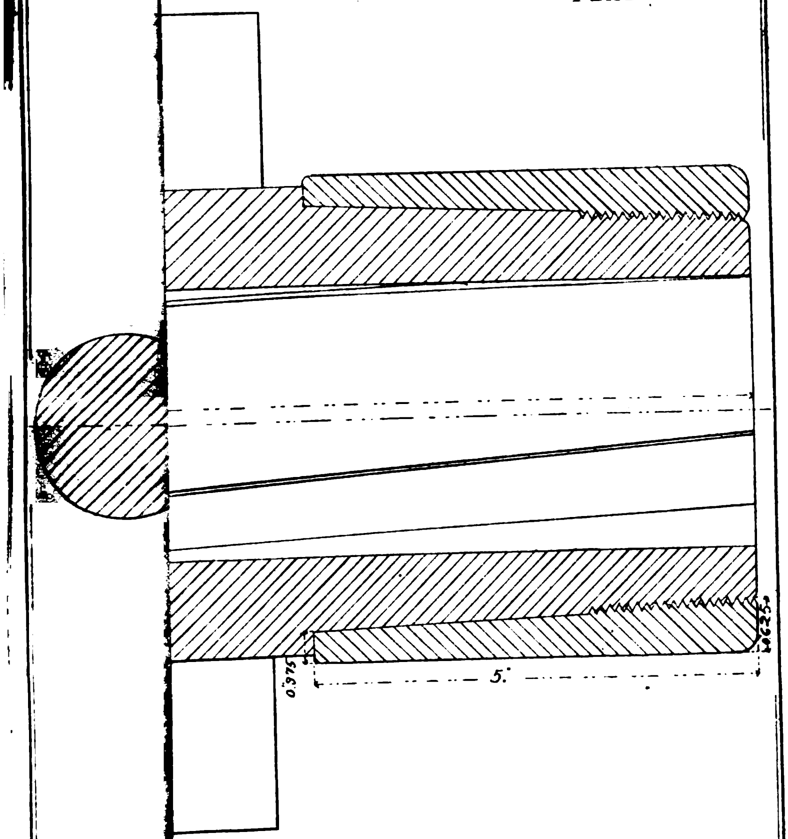
* Foot-pounds.

Temperature of the testing-room, 73° F.

C. B. RICHARDS, *Engineer*.

OFFICE OF THE COLT'S PATENT FIRE-ARMS MANUFACTURING COMPANY,
Hartford, June 26. 1878.

PLATE I.



IFE-SAVING APPARATUS.

THREE-INCH

LE-LOADING RIFLED MORTAR.

Converted from an old Bronze Gun.

Accompanying Appendix P, 1878

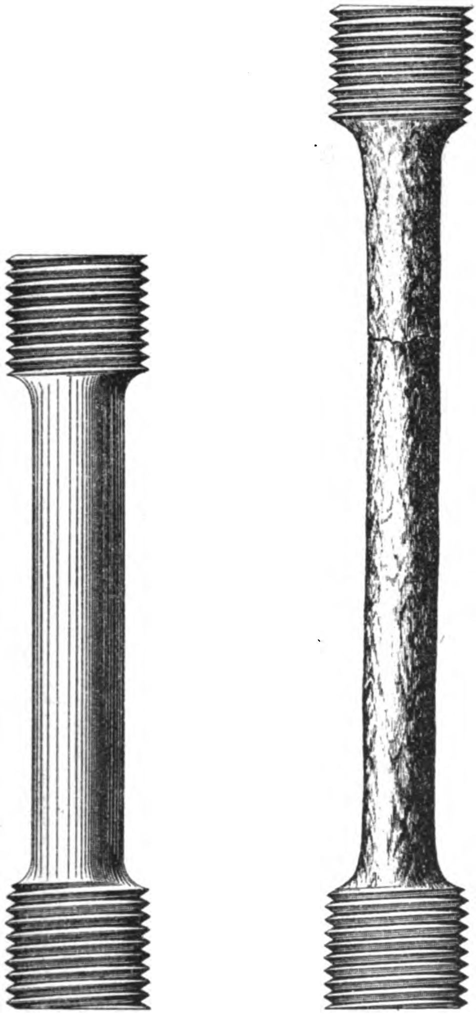
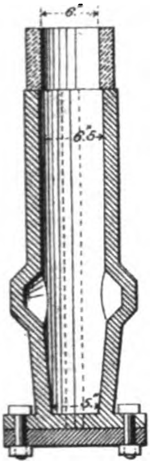


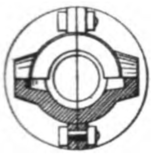
Fig. 17.

Accompanying Appendix P, 1878

Fig. 1

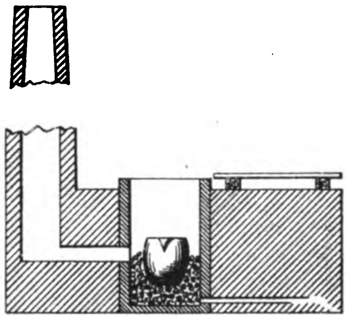


SECTION OF CHILL

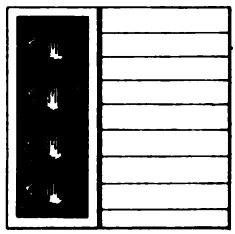


PLAN

Fig. 2



SECTION OF FURNACE

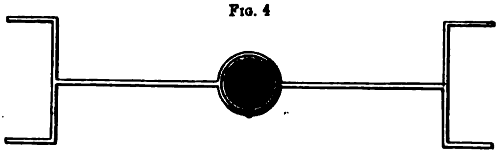


PLAN

Fig. 3

CRUCIBLE.

Fig. 4

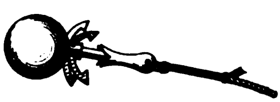


POURING LADLE.

Fig. 5

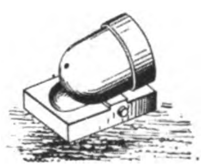
SHOT WITH LOOP
AND RAW HIDE STRAP

Fig. 6



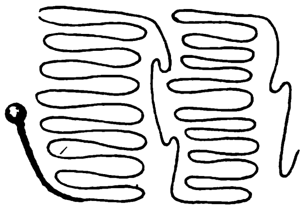
BARBED SHOT.

Fig. 7



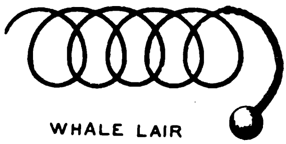
HOWITZER.

Fig. 1



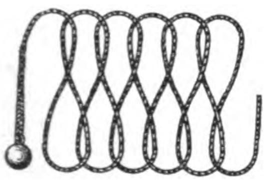
METHOD OF LAYING THE ROPE
(FRENCH FAKING)

Fig. 2



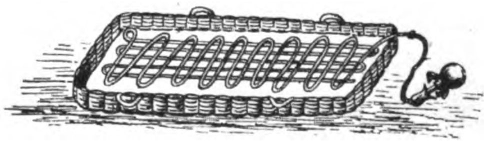
WHALE LAIR

Fig. 3



CHAIN FAKING

Fig. 4



ROPE READY IN BASKET

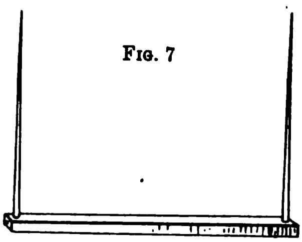
Fig. 5

PAPER TUBE

Fig. 6

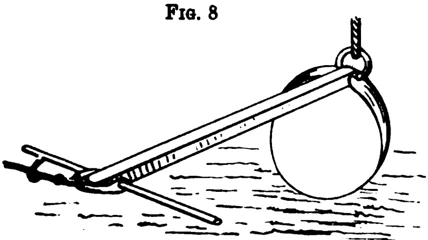
BALL WITH LID
FOR FUZE

Fig. 7



STAND

Fig. 8



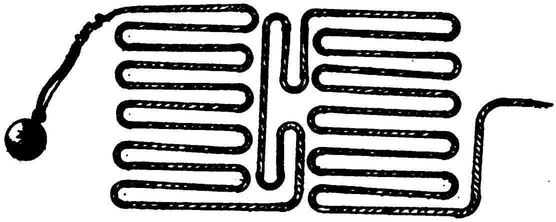
CAST IRON ANCHOR

Fig. 9

ROPE WITH STIFF LOOPS.

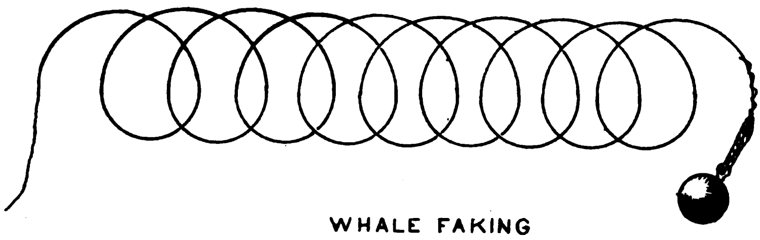
Accompanying Appendix P, 1878

Fig. 1



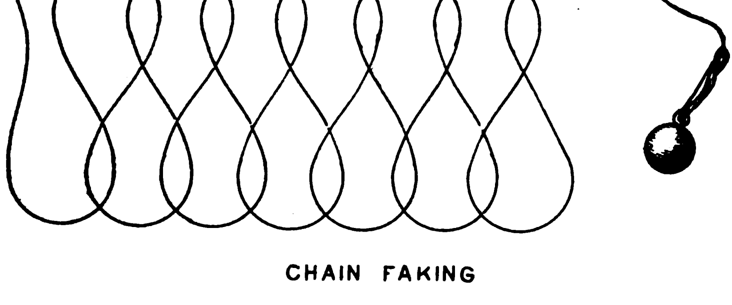
MODE OF FAKING THE ROPE

Fig. 2



WHALE FAKING

Fig. 3



CHAIN FAKING

Accompanying Appendix P, 1878

PARROTT'S PROJECTILE.

Fig. 1

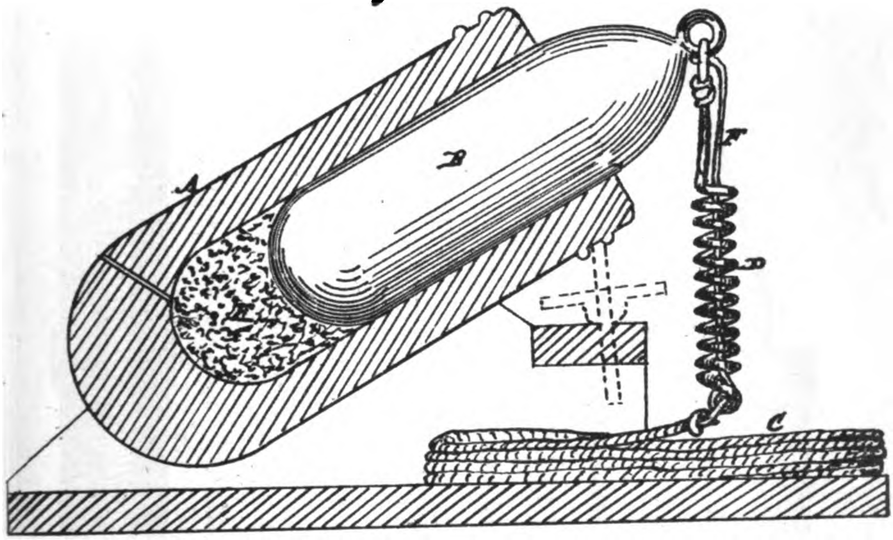
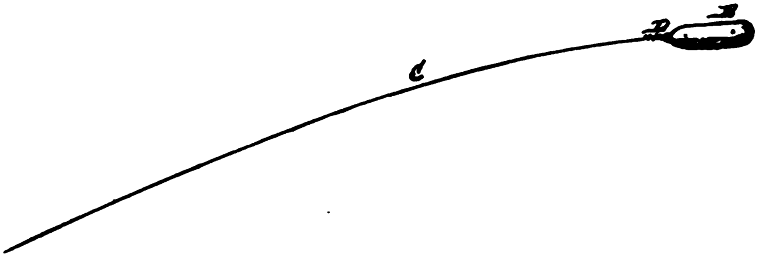


Fig. 2.



Accompanying Appendix P, 1878

PLATE LL.

E. S. HUNT.

Line-Throwing Apparatus.

No. 203,274. Patented May 7, 1878.

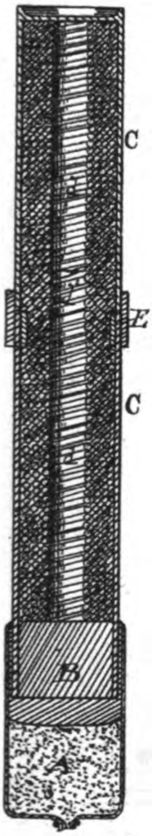


Fig. 1.

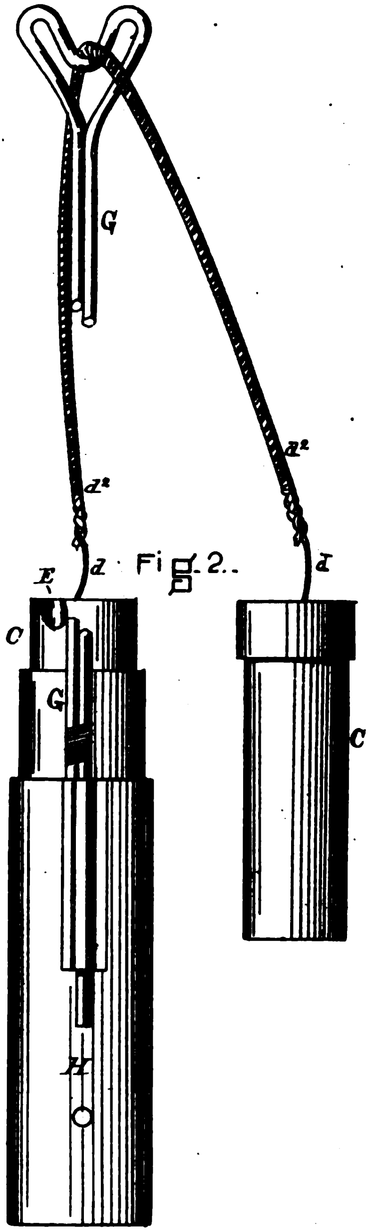
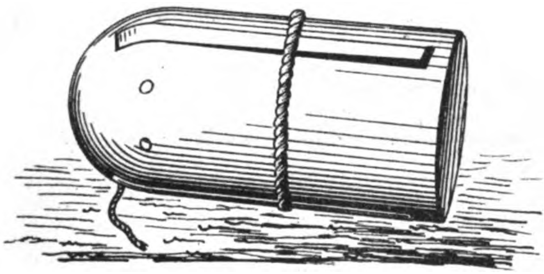


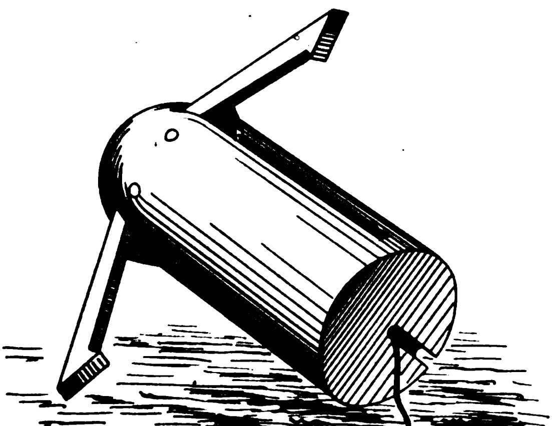
Fig. 2.

Accompanying Appendix P, 1878

CHANDLER ANCHOR SHOT



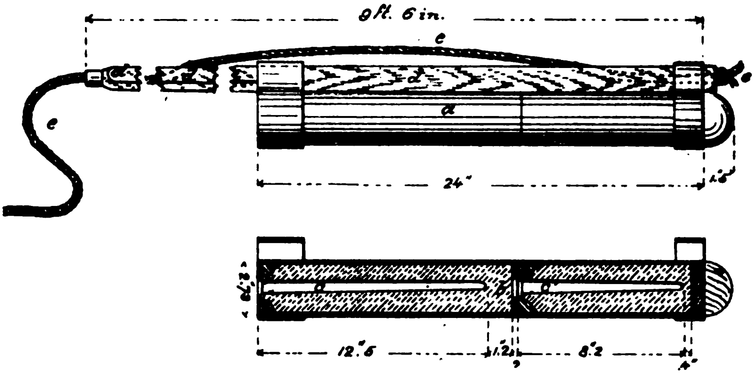
1. BEFORE FIRING



2. AFTER FIRING

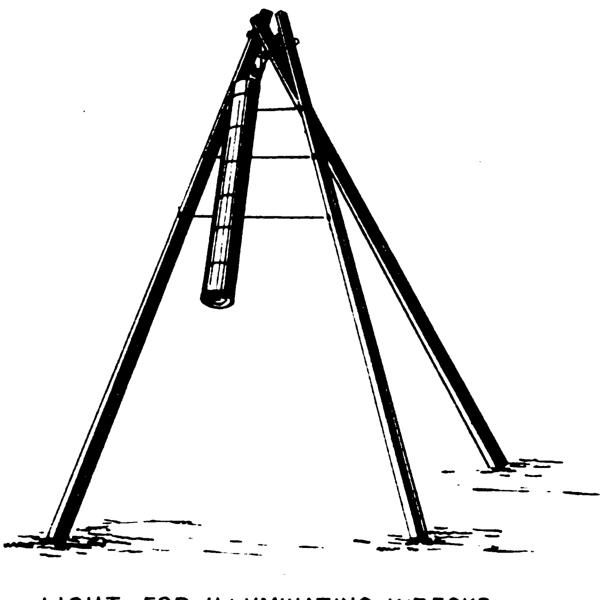
Accompanying Appendix P, 1878

Fig. 1



BOXER ROCKET

Fig. 2



LIGHT FOR ILLUMINATING WRECKS

Accompanying Appendix P. 1878

METHOD OF USING THE LIFE SAVING APPARATUS

Accompanying Appendix P, 1878

APPENDIX Q.

REPORT OF THE ORDNANCE BOARD ON THE EXPERIMENTAL GUNS PROCURED UNDER ACT OF JULY 6, 1872, WITH ESTIMATE FOR THEIR EXHAUSTIVE TRIAL, AS CONTEMPLATED BY LAW.

OFFICE OF THE ORDNANCE BOARD, U. S. A.,
New York, April 11, 1878.

SIR: Your communication of the 8th instant, regarding the experimental guns now on hand at Sandy Hook and awaiting trial, has received the attentive consideration of the board, and in compliance thereto it has to submit the following report:

Under the act of Congress approved June 6, 1872, appropriating funds for the procurement and tests of experimental rifled ordnance of heavy calibers (to be selected by a board of officers of the United States Army, to be appointed by the honorable Secretary of War), the department, under the authority of law, has procured, among others, several guns which are now on hand at the proving-ground at Sandy Hook awaiting trial. These guns are the Woodbridge, 10-inch rifle; the Thompson, 12-inch breech-loading rifle; the Sutcliffe, 9-inch breech-loading rifle; the Lyman, multicharge gun; and the Mann, 8-inch breech-loading rifle.

The inclosed statements show the kind of guns, the number of rounds so far fired from each, and their present condition.

It will be seen that the Woodbridge gun has been fired 10 rounds; the Thompson, 2 rounds; the Sutcliffe, 26 rounds; the Mann, 11 rounds; and the Multicharge gun, 3 rounds.

The extent of the tests so far made, it will be seen, are meager in the extreme, and no evidence of any special importance of the merits of any one of these experimental guns has consequently been obtained. They have been in the possession of the department, awaiting trial, for two or three years, but want of funds to undertake what may be regarded as a suitable proof has prevented the prosecution of the work. They were selected by a board of officers, after careful investigation as to their presumed merits as systems of construction (both breech and muzzle loaders), and have been procured at considerable expense to the government.

In view of the facts that they were provided for experiments and tests, and that none so far have been made to any extent, and in view of the developments to be expected regarding the numerous questions involved in gun constructions, both muzzle-loading and breech-loading; the interesting and important developments to be made in furtherance of the solution of the ballistic questions, now occupying the attention of the civilized world, and improvements to be developed in powders, projectiles, and systems of rifling, &c., the board is of the opinion that some measures looking to the trial of these guns and as contemplated by law of June 6, 1872, and to fully test these different inventions (recommended by the board organized under the act), should be instituted by the department for the procurement of a sufficient appropriation from Congress for the carrying on of the tests at as early a date as practicable.

The inclosed estimates in each case are therefore submitted for the consideration and action of the department. These estimates, it is believed, are sufficiently in detail to cover the grounds as to what is contemplated to be done in each case; also sufficiently itemized to show what materials

will have to be provided and what changes &c., will have to be made in constructions.

S. CRISPIN,
Brt. Col. U. S. A., Lieut. Col. of Ord., President of the Board.
T. J. TREADWELL,
Major of Ordnance.
T. G. BAYLOR,
Major of Ordnance.
FRANK H. PHIPPS,
Captain of Ordnance, Recorder of Board.

CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

Statement of the condition, and estimate of amounts required for the continuance of the trials of the following guns now at Sandy Hook, N. J.

Thompson, 12″ breech-loading rifle.
Woodbridge, 10″ muzzle-loading rifle.
Sutcliff, 9″ breech-loading rifle.
Mann, 8″.4 breech-loading rifle.
Lyman multicharge, 6″ rifle.

THOMPSON 12-INCH BREECH-LOADING RIFLE.

This gun is now at Sandy Hook, and in the same condition as when returned from the Centennial Exhibition. Its chamber has a capacity for only 50 pounds of powder, and it is rifled with seven grooves.

For transportation to and from South Boston foundery, rifling with 21 grooves, enlarging chamber for battering charge of 120 pounds, and providing gas-check and locking arrangement for breech-block	$5,000 00
For preparation of carriage	3,000 00
For platform and new butt	5,000 00
For labor, materials &c., in testing gun	2,375 00
For 500 rounds (120 pounds of powder)	18,000 00
For 250 projectiles	16,625 00
Total	50,000 00

WOODBRIDGE 10-INCH MUZZLE-LOADING RIFLE.

It is now lying dismounted at Sandy Hook and is in the same condition as was reported after the tenth round at Frankford arsenal. To be mounted for further trials, it will be necessary to finish up a carriage that was partially prepared for it and now on hand; this will cost $1,000, a platform, which will cost $2,500, 250 projectiles, $10,000; powder for 500 rounds, $12,000; repairs of butt, and labor, $3,000; making a total of $28,500 to complete 500 rounds.

SUTCLIFFE 9-INCH BREECH-LOADING RIFLE.

This gun, now mounted at Sandy Hook on a carriage prepared for it, has been fired as a 9-inch 26 times and should, in the opinion of the board, be fired up to 100 rounds as a 9″ caliber, the projectiles for this

purpose being now on hand—the additional cost for these 74 rounds will be, for powder $1,200; labor and repair of butt, $500.

It is the opinion of the board, and the desire of the inventor, that this gun should be bored up and rifled to a 10″ caliber; this will cost $1,500; for continuing the trial to 500 rounds as a 10″ caliber, it will cost, for powder, $8,400; for projectiles, $10,000; for repair of butt, labor, &c., $2,000; making, in all, $23,600. The gun is in good condition.

MANN 8.4-INCH BREECH-LOADING RIFLE.

This gun is now on hand, in good condition, at Sandy Hook, and a carriage ready for it. For further trial it should be rechambered for 40 pounds charge and a new gas-check prepared for it; this will cost $1,500; for powder, $6,000; for projectiles, $5,000; labor and repair of butts, $2,000; making, in all, $14,500.

LYMAN MULTICHARGE 6-INCH RIFLE.

The Lyman multicharge gun is at Sandy Hook. It has recently been furnished with a new breech-cap, putting it in good condition. Cost of further trial of same:

50 projectiles	$300 00
50 sabots	300 00
50 wads	400 00
Total	1,000 00

Summary of amounts required.

Thompson 12″ breech-loading rifle	$50,000 00
Woodbridge 10″ muzzle-loading rifle	28,500 00
Sutcliffe 9″ breech-loading rifle	23,600 00
Mann 8″.4 breech-loading rifle	14,500 00
Lyman 6″ multicharge	1,000 00
	117,600 00

WAR DEPARTMENT,
Washington City, April 19, 1878.

The Secretary of War has the honor to transmit to the House of Representatives a communication from the Chief of Ordnance, dated the 15th instant, and the papers accompanying the same, in regard to the five experimental guns, including "breech and muzzle loading cannon," procured by the Ordnance Department under the act of Congress of July 6, 1872.

The guns have been in the possession of the department for two or three years, but owing to lack of funds very few rounds have been fired from each gun. The necessity for the trial is fully set forth in the report of the Ordnance Board and of the Chief of Ordnance; an appropriation for the purpose of continuing and completing the trial is therefore respectfully recommended.

GEO. W. McCRARY,
Secretary of War.

The SPEAKER, *House of Representatives.*

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, April 15, 1878.

SIR: Under the act of Congress of July 6, 1872, five experimental guns, including breech and muzzle loading cannon, were procured by this department. These guns were designated by a board of officers appointed under the provisions of that act, and have been in the possession of this department for over two years. The inclosed report of the Ordnance Board shows the very few rounds each has been fired, and the necessity for exhaustive trials with these guns to carry out the intention of the law. There can be no question that their trial will develop much that will be of great value regarding the many important questions that enter into the construction of such heavy masses to enable them to endure the enormous strains to which they are subjected in their use as engines of war; and the ballistic questions involved, that now absorb the attention of the best scientific minds in the military profession, are of such importance in the determination of the best methods to utilize the industries of the country in preparing for the national defense, that an appropriation such as is recommended by the Ordnance Board is eminently in the interest of the public service. I therefore recommend that Congress be asked for an appropriation to enable this department to continue and complete the trial of these guns.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brig. Gen., Chief of Ordnance.

The honorable the SECRETARY OF WAR.

REPORTS OF THE CONSTRUCTOR OF ORDNANCE.

OFFICE OF THE CONSTRUCTOR OF ORDNANCE,
New York City, September 21, 1878.

SIR: I have the honor to inclose herewith reports on the construction of the following-named ordnance and carriage for 8-inch breech-loading rifle, to wit:

12.25-inch muzzle-loading rifle.
10-inch muzzle-loading rifle, converted from a 13-inch smooth-bore.
Converted 8-inch muzzle-loading rifle (breech insertion of lining).
Converted 8-inch breech-loading rifle (round-wedge fermeture).
Carriage for 8-inch breech-loading rifle, altered from a barbette carriage for 10-inch smooth-bore gun.

The above comprises all the experimental guns which have been constructed under the supervision of this office up to date and since the date of my last reports published with the report of the Chief of Ordnance for the year 1877.

In order to present a full report of the construction of the 12.25-inch rifle, portions of the preliminary report heretofore submitted had to be introduced in the inclosed report of its construction.

I am largely indebted to the services of Capt. Cullen Bryant and Lieuts. Charles S. Smith and C. W. Whipple, of the Ordnance Department, in the compilation of these reports from the data on the files of this office.

Very respectfully, your obedient servant,

S. CRISPIN,
Brt. Col. U. S. A., Lieut. Col. of Ord., Constructor of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

APPENDIX R.

CONSTRUCTION REPORT OF A 12.25-INCH MUZZLE-LOADING RIFLE. CAST-IRON CASING, LINED WITH COILED WROUGHT-IRON TUBE, INSERTED FROM THE MUZZLE. (SYSTEM No. 1.)

(One plate.)

THE 12.25-INCH MUZZLE-LOADING RIFLE.

DESCRIPTION OF THE GUN.

(Plate, Figure 2.)

The gun consists of a cast-iron body or casing of the Rodman model, lined with a coiled wrought-iron tube. It conforms in the general plan of its construction to the 8-inch converted rifle—wrought-iron lined—a full description of which has been given in previous reports. The only material point of difference is in the use of three additional securing pins to prevent the tube working in the casing.

RIFLING.

The rifling consists of 21 lands and grooves, each of equal width.

Width of lands and grooves	0.9163 inch.
Depth of grooves	0.09 inch.

Twist uniform, one turn in 70 feet.

The full depth of the rifling stops at a point 20 inches from the bottom of the bore, and the grooves are terminated with a uniform bevel 2 inches in length.

VENTING.

The vent is located parallel to the vertical plane through the axis of the bore and 3 inches to the left. It enters the bore at 9.5 inches from the bottom.

FABRICATION.

The tube was manufactured at the works of Sir William Armstrong, at Newcastle-upon-Tyne, England. It is of coiled wrought iron, and made upon the same plan as those used in the conversion of the 10-inch Rodman smooth-bores into 8-inch rifles. It was bored up to an interior diameter of 12″.227, in order to remove a defect found in the bore while in progress of manufacture.

The diameter and length of the tube when received were considerably in excess of the prescribed finished dimensions. It was subjected with satisfactory results to a water-proof of 375 pounds per square inch, and a careful inspection failed to discover any flaws or defects in its construction.

The casing was manufactured and the gun finished at the South Boston foundery.

The gun-casing was cast on the Rodman plan and cooled from the interior by a current of water. The pattern and flask for the mold were the same that were used in the construction of the Thompson 12-inch breech-loading rifle. These were altered to conform to the different

exterior dimensions, and a muzzle section 30 inches long was added to give the additional length required. A new core-barrel was provided on account of the increased diameter of the bore over the Thompson gun-casing.

FURNACES AND IRON.

The ordnance foundery, in which the gun-casing was cast, contains three reverberatory furnaces, all of which were charged to their full capacity. The grades and quantities of iron employed were as follows:

	Pounds.
No. 1. Dover pig-iron	22.500
No. 2. Dover pig-iron	22.500
No. 3. Dover pig-iron	22.500
No. 1. Muirkirk pig-iron	22.500
No. 2. Muirkirk pig-iron	22.500
No. 3. Muirkirk pig-iron	22.500
Remelted Dover and Muirkirk	47.400
Total	182.400

Each furnace was charged with equal weights of the different grades.

GUN–PIT AND FLASK.

The gun-pit in which the casing was cast is 11 feet in diameter and 22 feet in depth. The flask, when in the pit, extended about 7 feet above the top. To conduct the metal from the furnaces to the flask, the tap-hole of each furnace was connected by a runner with a common reservoir or basin for mixing the charge; thence two runners extended to the flask, connecting with side runners on opposite sides and at points about 4 feet 8 inches from the top, which was as high as the flow of metal from the furnaces could reach. To fill the flask above this height, it was arranged that a portion of the charge of one of the furnaces should be drawn off into ladles, to be poured in at the top.

CASTING.

The fires were kindled in furnaces Nos. 2 and 3 at 3.30 a. m., and in No. 1 at 4 a. m., May 30, 1877. The metal was down in all the furnaces by 12.30 p. m., though No. 1 preceded the others by fully half an hour, on account of being more advantageously located for feeding the fires. Tests of the metal in fusion were made at various intervals. At 4.40 p. m., it was found to be in proper condition in all the furnaces, and they were tapped simultaneously. In 15 minutes the mold was filled to the level of the runners from the basin. The flow of metal from the furnaces was then stopped and the connecting apertures closed. Two large ladles of metal, which had meanwhile been drawn from one of the furnaces, were quickly poured in at the top of the flask, which filled it to within 20 inches of the surface. The remaining space was filled by adding three small ladles of metal, the last one being poured at 5.45 p. m. It was found, however, the next morning, that the surface of the casting had sunk several inches during the night, and more metal was then added.

COOLING.

The water was let into the core-barrel at the same moment that the furnaces were tapped, and circulated for 42 minutes at the rate of 60 gallons per minute. It was then diminished to 36 gallons per minute,

at which rate the circulation was continued until shut off for the purpose of withdrawing the core-barrel. Fires were lighted in the pit at 6.06 p. m., and were kept burning for about 60 hours. The flow of water was stopped 24 hours after casting and the core-barrel removed. The water was then injected into the gun, and after a short interval the rate of circulation was fixed at 26 gallons per minute, and continued until 118½ hours after casting, when it was shut off, excepting a small stream of half a gallon per minute, which was allowed to circulate for 14½ hours longer. The details of the cooling are given in the "statement of fabrication." (Table No. 1.)

TURNING AND BORING.

When the gun had become thoroughly cooled, the flask was removed, and the outside cleaned of as much of the scale as came off readily. The hoisting from the pit was attended with some delay and difficulty, as the foundery-cranes were too light for the purpose, and additional hoisting machinery had to be erected temporarily. It was finally accomplished on the twelfth day after casting, and the gun was lowered upon skids alongside the pit. The remainder of the scale was chipped off from the exterior, and the bore was cleaned, as far as practicable, after being treated with a solution of diluted sulphuric acid to soften the scale. The gun was then transferred to the machine-shop, and placed in the heading-lathe. While in this machine, the greater portion of the superfluous metal of the chase was removed by cutting in at short intervals to within 2 or 3 inches of the required diameter, and then breaking out the intervening rings with chisel and hammer. A ring for testing purposes, 3½ inches thick, was cut next to the muzzle, and, as soon as work upon the chase was sufficiently advanced, was detached, together with the sinking-head.

The gun was next transferred to a boring-lathe, where the operations of boring and turning could be carried on at the same time. In this machine the bore was finished for the reception of the tube and the exterior, with the exception of the trunnion section and the extremity of the breech, turned down to the prescribed dimensions.

A careful inspection at this stage of the work showed the bore to be smooth and free from flaws, and no defects of importance were found on the exterior.

Measurements with the star-gauge showed a diameter of bore varying only from 19″.494 to 19″.496, and the eccentricity nowhere exceeded 0″.002.

The straightness of the bore was verified by a cylinder-gauge 60″ in length and 19″.49 in diameter, which was inserted to the bottom and withdrawn without difficulty. To finish the trunnion section of the exterior, the casing was placed in a trunnion-lathe and the trunnions turned down to their proper dimensions, while the greater part of the excess of metal between was removed by a planing-machine working at the same time. The sight seat and rimbases were next finished by chipping off the surplus metal by hand and filing down, and an indicator-hole for the gas-escape was bored near the breech.

As soon as the diameter of bore of the casing was determined, the tube was placed in a lathe and the exterior finished to a diameter varying uniformly from 19″.488 near the breech to 19″.483 in the vicinity of the muzzle, thereby allowing a play between tube and casing varying from 0″.007 to 0″.013.

The tube now being ready for insertion, the casing was placed in position upon two lathe-beds, with the muzzle slightly elevated. The tube

was suspended by slings to a truck-crane, and having been thoroughly oiled and the breech smeared with red lead, was swung in front of the casing and inserted as far as the slings would permit; these were then shifted forward by changing the position of the crane, and the tube was allowed to slide gradually down until it reached the bottom. No difficulties on account of sticking or binding were encountered. The tube was then withdrawn and the operation of insertion repeated until by filing the bottom of the tube a thorough contact was secured between it and the bottom of the bore of the casing. After this had been accomplished the tube was placed in the rifling-machine and rifled. It was then finally inserted, and the muzzle-collar, which had been finished in the mean time, was fitted and screwed home.

The gun now being assembled, it was placed in the heading-lathe and the muzzle faced; holes were drilled for the vent-piece and securing-pins, which were inserted in their places.

Finally the breech-square, which had been left at the breech for handling the gun in the lathe, was turned down until it could be broken off, which was done by blows from a sledge hammer, and the breech was finished by chipping off the remainder of the surplus metal by hand.

TESTS.

The ring taken from next the muzzle of the gun was tested for initial tension, and specimens were afterward taken out for ascertaining the tenacity and density of the metal. The results are given in table No. 1.

The metal of the ring in several places was quite spongy—indicating an insufficient length and weight of sinking-head—and considerable difficulty was experiened on this account in securing suitable specimens for the test. The ring was taken from that part of the casting where the metal was poured in from ladles (and consequently was somewhat cooled). It is not certain, therefore, that the specimens taken from it correctly indicate the physical properties of the metal in the gun which came direct from the furnaces. An outside specimen, taken from the gun 19 inches from the muzzle, was tested, and gave results materially different from specimens taken from the ring. (See Table No. 1.)

INSPECTION.

The inspections made at various times during the progress of the construction showed the workmanship of the gun to be satisfactory throughout.

The gun when finished (December 21, 1877) was sent to the proving-ground at Sandy Hook, N. J., for proof and trial.

PRINCIPAL DIMENSIONS.

	Inches.
Diameter at muzzle	27.55
Diameter at 18 inches from muzzle	27.55
Diameter at 38 inches from muzzle	27.70
Diameter at 58 inches from muzzle	29.38
Diameter at 78 inches from muzzle	31.78
Diameter at 98 inches from muzzle	34.83
Diameter at 118 inches from muzzle	38.48
Diameter at 138 inches from muzzle	42.68
Diameter at 158 inches from muzzle	47.08
Diameter at 178 inches from muzzle	50.93
Diameter at 198 inches from muzzle	53.78
Diameter (maximum) at 218 inches from muzzle	55
Diameter at breech	47.16
Diameter at neck	41.60
Diameter of trunnions { right	15
Diameter of trunnions { left	15

		Inches.
Diameter of rimbases	right	17
	left	17
Total length of gun		262.92
Length of trunnions	right	6.31
	left	6.32
Distance between rimbases		55.09
Distance from axis of trunnions to face of muzzle		167.67
Distance from axis of trunnions to rear of breech		95.25
Distance of axis of trunnions from axis of bore		.005
Total length of tube		232.12
Total length of bore of casing		232.12
Maximum eccentricity of bore of casing		.002
Length of B tube		59.86
Depth of wrought-iron cup at bottom of tube		5.07
Thickness at bottom of wrought-iron cup		5
Diameter of finished tube, from bottom to 60 inches		19.486 19.488
Diameter of bore of casing from bottom to 60 inches		19.494 19.496
Corresponding play		.009
Diameter of finished tube, from 60 inches from bottom to muzzle		19.483 19.486
Diameter of bore of casing, from 60 inches from bottom to muzzle		19.494 19.496
Corresponding play		.013
Length of neck of tube under muzzle collar		6.96
Length of muzzle collar		6.96
Length of recess in casing		7.42
Length of screw on muzzle collar		4.875
Length of screw on recess in casing		4.75
Excess in length of screw on collar over that on recess		.125
Diameter of tube over neck		16.506
Interior diameter of muzzle collar		16.51
Corresponding play		.004
Diameter of muzzle collar across threads		19.992
Diameter of recess on casing		19.999
Play between collar and casing		.007
Thickness of collar		1.741
Pitch of thread on collar		.75
Radius of curve at bottom of bore of casing		2.18
Radius of curve at bottom of tube		2.25
Diameter of gas channel through casing		.23
Distance of interior orifice below axis of bore		7.06
Distance of exterior orifice from tangent to bottom of gun		18.16
Length of bore of A tube		227.11
Length of rifled portion of tube		206.90
Diameter of bore across lands		12.227 12.247
Width of grooves		.916
Width of lands		.9166
Depth of grooves		.091
Pitch of rifling	feet	70
Diameter of vent		.2
Diameter of vent bushing		1
Axis of vent from bottom of bore		9.2
Axis of vent from verticalplane through axis of bore		3.15
Length of securing-pins	No. 1	5.06
	No. 2	5.55
	No. 3	9.52
	No. 4	11.68
Diameter of securing-pins	No. 1	1.504
	No. 2	1.50
	No. 3	2
	No. 4	2
Distance of securing-pins from muzzle	No. 1	28.08
	No. 2	48.05
	No. 3	105.58
	No. 4	128.84
Weight of gun	pounds	89,350
Counter preponderance	pounds	51

TABLE No. 1.

Foundery history of the 12.25-inch muzzle-loading rifle, manufactured at the South Boston Foundery, Boston, Mass.

CHARGE.

Iron used.

Grade of iron.	Furnaces. No. 1.	No. 2.	No. 3.	Total.
No. 1	15,000	15,000	15,000	45,000
No. 2	15,000	15,000	15,000	45,000
No. 3 (hard) / No. 3 (soft)	15,000	15,000	15,000	45,000
Remelted	15,800	15,800	15,800	47,400
	60,800	60,800	60,800	182,400

Coal consumed.

	Furnaces. No. 1.	No. 2.	No. 3.	Total.
Melting	....	....	....	57,000
Fusion	....	....	....	27,000
	....	....	....	84,000

Character of test-sticks.

	Furnaces. No. 1.	No. 2.	No. 3.	Basin.
Iron	Nearly white.	Mottled.	Slightly mottled	None taken.

Record of casting.

May 30:

Furnaces fired at	3.30 and 4 a. m.
Metal down at	12.30 p. m.
Time of melting	9 hours.
Time in fusion	$4\frac{1}{6}$ hours.
Gun cast at	4.40 p. m.
Time occupied in casting	15 minutes.
Temperature of water entering core-barrel	62 degrees.
Temperature of water leaving core-barrel (45 minutes)	113 degrees.
Rate of water per minute	36 gallons.
Fire kindled in pit	6.06 p. m.

June 2:

Fire in pit went out	6.00 a. m.
Fire in pit burned	60 hours.

May 31:

Water shut off at	5.00 p. m.
Core-barrel removed at	6.45 p. m.
Water entered gun at	6.57 p. m.
Temperature of water entering gun	64 degrees.
Temperature of water leaving gun in 13 minutes	136 degrees.
Total time in cooling gun	$119\frac{1}{4}$ hours.

Cooling-tables.

Core-barrel.		Core-barrel removed.							
Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees
1	110	23	84	45	129	67	87	89	72
2	106	24	83	46	128	68	85	90	72
3	104	25	....	47	127	69	84	91	70
4	102	26	....	48	126	70	83	92	70
5	100	27	185	49	126	71	81	93	70
6	98	28	179	50	125	72	81	94	70
7	100	29	169	51	123	73	81	95	70
8	100	30	159	52	121	74	80	96	70
9	100	31	150	53	119	75	79	97	70
10	100	32	146	54	117	76	78	98	70
11	102	33	139	55	114	77	78	99	70
12	100	34	134	56	110	78	76	100	70
13	100	35	140	57	105	79	76	101	70
14	100	36	142	58	101	80	75	102	70
15	100	37	144	59	99	81	75	103	70
16	99	38	146	60	97	82	75	104	70
17	90	39	143	61	95	83	75	105	70
18	90	40	138	62	93	84	75	106	69
19	89	41	136	63	92	85	74	107	69
20	88	42	134	64	91	86	74	108	69
21	87	43	132	65	89	87	74	109	68
22	86	44	131	66	88	88	74	110	68

Mechanical tests.

Specimens.	Density.	Tenacity.
No. 6 (outside)*	7.3454	39,900
No. 8 (middle)*	7.2717	33,000
No. 4 (inside)*	7.2731	30,000
No. 8 (outside)†	7.3374	40,794
No. 8 (middle)†	7.2698	34,346
No. 1 (inside)†	7.3155	40,704
Radial specimen‡	7.2728	33,881

* Specimens tested at the United States ordnance agency.
† Specimens tested at the foundery.
‡ Specimen taken from outside of gun at about 19 inches from muzzle.

Initial tension.

Exterior diameter of ring	49''.00
Interior diameter of ring	17''.75
Thickness of ring	3''.54
Thickness of broken section	0''.58
Interior of opening	0''.068
Exterior of opening	0''.184
Circumference of exterior of ring	153''.938
Exterior per inch of circumference	0''.001195
Initial tension	19,500

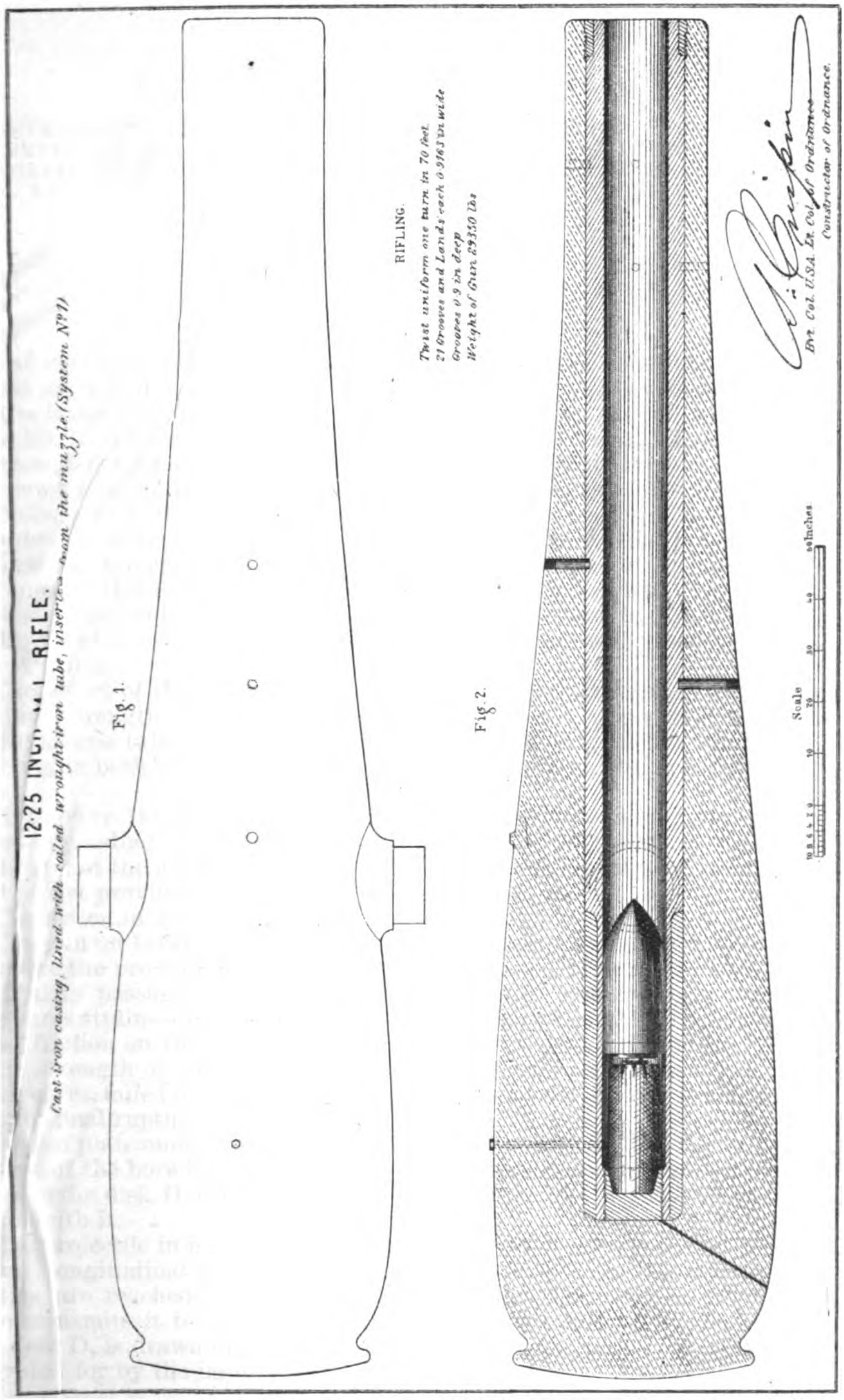
REMARKS.—Equal quantities of Dover and Muirkirk were used in charging the furnaces. Record of coal consumed was not kept for the different furnaces. Furnaces Nos. 2 and 3 fired at 3.30; No. 1 at 4 a. m. Cooling tables represent the temperature at which the water left the core-barrel and gun. Temperature was at 68° when the water was shut off.

Table No. 2.

Table showing relative diameters of interior of casing of 12.25-inch muzzle-loading rifle, and exterior of tube inserted therein.

Inches from muzzle.	Diameter of bore of casing.	Exterior diameter of tube.	Difference or play of tube.	Inches from muzzle.	Diameter of bore of casing.	Exterior diameter of tube.	Difference or play of tube.
	″	″	″		″	″	″
229	19.494	19.487	0.007	152	19.495	19.485	0.010
228	19.494	19.487	.007	150	19.495	19.485	.010
227	19.494	19.487	.007	148	19.495	19.485	.010
226	19.496	19.497	.009	146	19.495	19.485	.010
225	19.496	19.487	.009	144	19.495	19.485	.010
224	19.496	19.487	.009	142	19.495	19.485	.010
223	19.496	19.488	.008	140	19.495	19.485	.010
222	19.496	19.488	.008	138	19.495	19.485	.010
221	19.495	19.488	.007	136	19.495	19.485	.010
220	19.496	19.488	.008	134	19.494	19.485	.009
219	19.496	19.488	.008	132	19.494	19.485	.009
218	19.496	19.488	.008	130	19.494	19.485	.009
217	19.496	19.488	.008	128	19.494	19.485	.009
216	19.496	19.488	.008	126	19.494	19.485	.009
215	19.496	19.488	.008	124	19.495	19.485	.010
214	19.496	19.488	.008	122	19.494	19.485	.009
213	19.496	19.488	.008	120	19.494	19.485	.009
212	19.496	19.488	.008	118	19.494	19.485	.009
211	19.496	19.488	.008	116	19.494	19.485	.009
210	19.496	19.488	.008	114	19.494	19.485	.009
209	19.496	19.488	.008	112	19.494	19.485	.009
208	19.496	19.488	.008	110	19.494	19.485	.009
207	19.496	19.487	.009	108	19.494	19.485	.009
206	19.496	19.487	.009	106	19.495	19.485	.010
205	19.496	19.487	.009	104	19.494	19.485	.009
204	19.496	19.487	.009	102	19.495	19.485	.010
203	19.496	19.487	.009	100	19.494	19.483	.011
202	19.495	19.487	.008	98	19.495	19.483	.012
201	19.496	19.487	.009	96	19.495	19.483	.012
200	19.496	19.487	.009	94	19.494	19.483	.011
199	19.496	19.487	.009	92	19.495	19.483	.012
198	19.496	19.487	.009	90	19.494	19.483	.011
197	19.496	19.487	.009	88	19.494	19.483	.011
196	19.495	19.487	.008	86	19.494	19.483	.011
195	19.495	19.487	.008	84	19.494	19.483	.011
194	19.495	19.487	.008	82	19.495	19.483	.012
193	19.495	19.487	.008	80	19.494	19.483	.011
192	19.495	19.487	.008	78	19.495	19.483	.012
191	19.494	19.487	.007	76	19.495	19.483	.012
190	19.494	19.487	.007	74	19.495	19.483	.012
189	19.494	19.487	.007	72	19.495	19.483	.012
188	19.495	19.487	.008	70	19.495	19.483	.012
187	19.494	19.487	.007	68	19.495	19.483	.012
186	19.494	19.487	.007	66	19.495	19.483	.012
185	19.494	19.487	.007	64	19.494	19.483	.011
184	19.494	19.487	.007	62	19.495	19.483	.012
183	19.494	19.487	.007	60	19.494	19.483	.011
182	19.494	19.487	.007	58	19.495	19.483	.012
181	19.494	19.487	.007	56	19.495	19.483	.012
180	19.494	19.487	.007	54	19.495	19.483	.012
179	19.494	19.487	.007	52	19.495	19.483	.012
178	19.494	19.487	.007	50	19.494	19.483	.011
177	19.494	19.487	.007	48	19.495	19.483	.012
176	19.464	19.487	.007	46	19.494	19.483	.011
175	19.494	19.487	.007	44	19.494	19.483	.011
174	19.494	19.486	.008	42	19.494	19.483	.011
173	19.494	19.486	.008	40	19.494	19.483	.011
172	19.494	19.486	.008	38	19.494	19.483	.011
171	19.495	19.486	.009	36	19.495	19.483	.012
170	19.494	19.486	.008	34	19.495	19.483	.012
169	19.494	19.486	.008	32	19.495	19.483	.012
168	19.494	19.486	.008	30	19.495	19.483	.012
167	19.494	19.486	.008	28	19.495	19.483	.012
166	19.495	19.486	.009	26	19.495	19.483	.012
165	19.495	19.486	.009	24	19.496	19.483	.013
164	19.494	19.486	.008	22	19.496	19.483	.013
163	19.495	19.486	.009	20	19.496	19.483	.013
162	19.495	19.486	.009	18	19.495	19.483	.012
161	19.495	19.486	.009	16	19.495	19.483	.012
160	19.494	19.485	.009	14	19.495	19.483	.012
158	19.495	19.485	.010	12	19.495	19.483	.012
156	19.495	19.485	.010	10	19.495	19.483	.012
154	19.495	19.485	.010	8	19.495	19.483	.012

PLATE I.



Accompanying Appendix R 1878

APPENDIX R 1.

CONSTRUCTION REPORT OF 10-INCH MUZZLE-LOADING RIFLE, CONVERTED FROM A 13-INCH RODMAN SMOOTH-BORE, BY LINING WITH A COILED WROUGHT-IRON TUBE, INSERTED FROM THE MUZZLE. (System No. 2.)

(One plate.)

DESCRIPTION OF THE GUN.

(Plate I, Fig. 2.)

The cast-iron casing C consists of a 13-inch Rodman smooth-bore gun, bored up to a diameter of 17 inches. The tube is of coiled wrought iron, and is inserted and secured in the casing in the same manner as in system No. 1. The inner or A tube is made in two sections. The breech section A′ is joined to the muzzle section A by counter-boring and cutting a screw-thread in the latter for its reception. The section A′ is united by shrinkage with the outer or B tube. The latter tube, for a distance of 5 inches from its joint with the muzzle section of the A tube, is bored to an interior diameter of 13 inches, and for the remainder of its length to 13.5 inches, thereby forming the shoulder *a a*, 0″.25 in height. It extends 2.5 inches beyond the A′ tube at the rear, and the bottom is closed by the disk D, which is screwed in and forms a close contact with the breech of the A′ tube.

The object of this form of construction is to secure an increased longitudinal strength to the system of lining cast-iron guns with coiled wrought-iron tubes. By this arrangement all the longitudinal strength existing in both the inner or A′ tube and the B tube can be brought into play.

Heretofore the B has only been shrunk on without a shoulder, and thus only aiding the inner tube (longitudinally) by the resulting friction, and has not the advantage of the positive locking together of the tube and jacket provided for by this form of construction.

The action in actual practice will be as follows:

The gun on being discharged, the powder impresses on the bottom of the bore the pressure of its gases, and also on the projectile. The latter, in its passage through the bore—especially when the maximum pressures attain—creates considerable and dangerous longitudinal strains from friction on the surface of the bore, calling into play the longitudinal strength of the inner tube, which, ordinarily constructed, has, in some cases, failed (as experiments have shown) to sustain the strain, and longitudinal rupture has ensued.

By the plan under consideration the screw-cup E, held firmly at the bottom of the bore by the developed gases, transmits the pressure it sustains to the disk D, which in turn holds the outer tube or jacket B by its union with it.

The projectile in its passage through the bore throws a powerful (frictional) longitudinal strain on the inner tube, which, when the maximum strains are reached, transmits the thrust to the shoulder *a a*. This in turn transmits it to the jacket B, which being secured at the base by the disk D, is drawn upon for its longitudinal strength, in the manner provided for by the improvement presented.

RIFLING AND VENTING.

The gun is rifled with 17 lands and grooves, each of equal width. The full depth of rifling stops at 18 inches from the bottom of the bore, and the grooves are connected with the unrifled portion of the bore by a bevel 1″.5 in length.

Width of grooves and lands	0.924 inch.
Depth of grooves	0.08 inch.

Twist uniform, one turn in 50 feet.

The vent is located 2″.5 from, and parallel to, a vertical plane through the axis of the bore, and enters 4″.5 from the bottom.

FABRICATION.

The work of conversion was performed at the South Boston Foundery. The gun used for the casing was a 13-inch Rodman smooth-bore, manufactured at the same foundery, and inspected and proved in 1866.

The gun was placed in a boring-lathe and bored up to 17 inches; the recess for the muzzle-collar was bored and tapped, and the indicator-hole for the gas-escape bored.

The several parts of the tube as received at the foundery were bored under size and rough turned, so as to leave a slight excess of metal above the required diameters. To join these parts the B tube was bored up to the required diameter, and the thread cut at the breech for the disk. The muzzle section of the A tube was counter-bored, threaded, and beveled for the reception of the breech section. The latter section was then finished at the joint, so as to make as near as practicable a mechanical fit, while the remainder of the exterior was turned to a diameter to enter the B tube under a shrinkage of about 0″.003. The spiral groove for the gas-escape was then cut and the breach squared off and finished.

To shrink the two parts together, the B tube was placed vertically, breech upward, upon the end of a hollow cast-iron cylinder, with an interior diameter large enough to admit of the free passage of the front end of the breech section of the A tube. It (the B tube) was then inclosed in a cylinder of sheet-iron and heated up by a wood-fire until the interior diameter had expanded 0″.06.

The section of the A tube after being filled with cold water, which was confined in the bore by a wooden plug, was attached to a crane and lowered into the B tube until the shoulders on each came in contact. A stream of water was then turned upon the B tube and continued until it was thoroughly cooled. The disk D was then screwed into its place at the breech.

The surfaces of contact of the joints (*s s*, see drawing) of the two sections of the tube as now assembled, were next turned down and fitted to the front section of the A tube, until as close a junction was secured as was practicable. The sections were then screwed together and the tube turned down in a lathe to the required dimensions for insertion in the casing, and afterward bored up to the prescribed diameter and rifled.

The mode of inserting the tube was identical with that employed in the construction of the 12.25 inch rifle.

After the insertion of the tube the vent-piece and securing-pins were inserted in their places and the muzzle faced. The tube and muzzle-collar were allowed to project 1″.5 beyond the muzzle of the casing.

INSPECTION.

The inspections made at various times during the progress of the work were satisfactory with regard to the workmanship of the tube. The bore of the casing was found not to be perfectly true, and required considerable enlargement by grinding at certain points, before the tube could be inserted to the bottom.

PRINCIPAL DIMENSIONS.

Total length of tube	153.22	inches.
Total length of bore of casing	151.70	inches.
Maximum eccentricity of bore of casing	.029	inch.
Length of B tube	48.88	inches.
Interior diameter of B tube	13.501 13.510	inches. inches.
Diameter of A′ tube underneath B tube	13.503 13.514	inches. inches.
Shrinkage	0.004	inches.
Depth of gas-escape on A tube	.05	inch.
Width of gas-escape on A tube	0.1	inches.
Pitch of spiral of gas-escape	10	inches.
Depth of wrought-iron cup at bottom of tube	3.48	inches.
Thickness at bottom of wrought-iron cup and disk. cup	3.50	inches.
Thickness at bottom of wrought-iron cup and disk. disk	2.50	inches.
Diameter of cup, over threads	9.8	inches.
Pitch of thread on cup	0.3	inches.
Diameter of interior of cup, at top	8.2	inches.
Diameter of interior of cup, at bottom	7.2	inches.
Diameter of finished tube, from bottom to 48 inches	16.970 16.984	inches. inches.
Diameter of bore of casing, from bottom to 48 inches	17.011 17.047	inches. inches.
Corresponding play	.064	inch.
Diameter of finished tube, from 48 inches, from bottom to muzzle	16.984 16.986	inches. inches.
Diameter of bore of casing, from 48 inches, from bottom to muzzle	17.009 17.022	inches. inches.
Corresponding play	.038	inch.
Length of neck of tube under muzzle-collar	7.50	inches.
ength of muzzle-collar	7.50	inches.
ength of recess in casing	6.59	inches.
Length of screw on muzzle-collar	4.40	inches.
Length of screw on recess in casing	4.25	inches.
Excess in length of screw on collar over that on recess	.15	inch.
Diameter of tube over neck	14.705	inches.
Interior diameter of muzzle-collar	14.710	inches.
Corresponding play	.005	inch.
Diameter of muzzle-collar across threads	17.506	inches.
Diameter of recess on casing	17.522	inches.
Play between collar and casing	.016	inch.
Thickness of collar	1.398	inches.
Pitch of thread on collar	.75	inch.
Radius of curve at bottom of bore of casing	1.95	inches.
Radius of curve at bottom of tube	2.00	inches.
Diameter of gas-channel through casing	.2	inch.
Distance of interior orifice below axis of bore	6.5	inches.
Distance of exterior orifice from tangent to bottom of gun	11.66	inches.
Length of bore of A tube	147.22	inches.
Length of rifled portion of bore	129.08	inches
Diameter of bore across lands	10.000 10.004	inches inches
Width of grooves	.923	inch.
Width of lands	.925	inch.
Depth of grooves	.084 .087	inch. inch.
Pitch of rifling	50	feet.
Diameter of vent	.2	inch.

Diameter of vent-bushing	1.01 inches.
Axis of vent from bottom of bore	4.40 inches.
Axis of vent from vertical plane through axis of bore	2.46 inches.
Length of securing-pin	7.98 inches.
Diameter of securing-pin	2.01 inches.
Distance of securing-pin from muzzle	73.72 inches.
Weight of gun	40,320 pounds.
Counter-preponderance	0

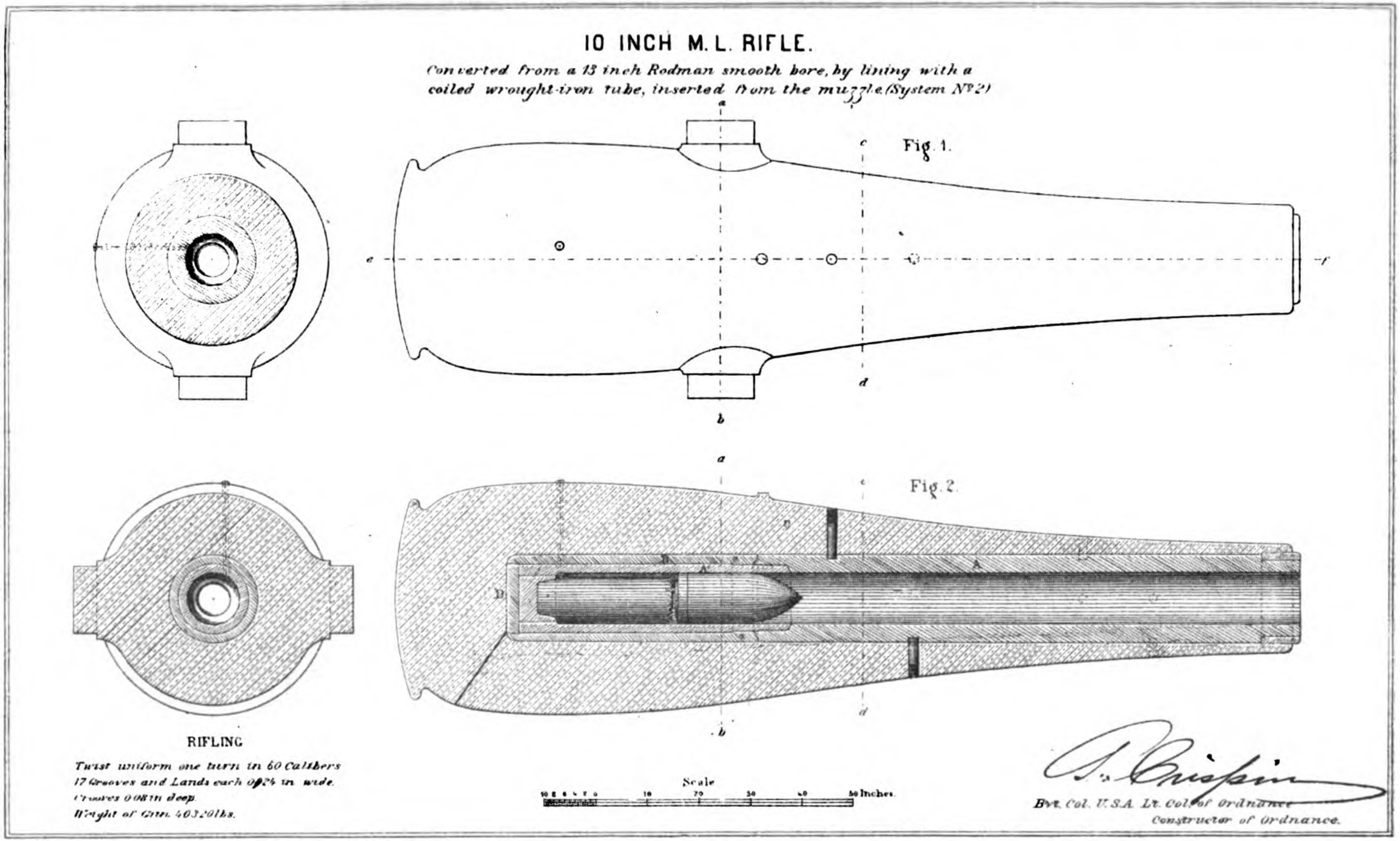
The gun when finished was sent to Sandy Hook for proof and trial.

No. 1.

Table showing relative diameters of interior of casing of 10-inch muzzle-loading rifle and exterior of the tube inserted therein.

Distance from muzzle.	Diameter of bore of casing.	Exterior diameter of tube.	Difference or play of tube.	Distance from muzzle.	Diameter of bore of casing.	Exterior diameter of tube.	Difference or play of tube.
"	"	"	"	"	"	"	"
149	17.011	16.970	0.041	99	17.013	16.984	.029
148	17.015	16.971	.044	98	17.014	16.984	.030
147	17.017	16.971	.046	97	17.013	16.984	.029
146	17.022	16.974	.048	96	17.012	16.984	.028
145	17.025	16.979	.046	95	17.012	16.984	.028
144	17.027	16.981	.046	94	17.012	16.984	.028
143	17.029	16.981	.048	93	17.011	16.984	.027
142	17.031	16.981	.020	92	17.011	16.984	.027
141	17.034	16.982	.052	91	17.012	16.984	.028
140	17.036	16.982	.054	90	17.012	16.984	.028
139	17.037	16.983	.054	88	17.016	16.984	.032
138	17.039	16.983	.056	86	17.022	16.984	.038
137	17.041	16.983	.058	84	17.020	16.985	.035
136	17.042	16.983	.059	82	17.017	16.985	.032
135	17.043	16.983	.060	80	17.016	16.985	.031
134	17.044	16.983	.061	78	17.015	16.985	.030
133	17.046	16.983	.063	76	17.013	16.985	.028
132	17.046	16.983	.063	74	17.015	16.985	.030
131	17.047	16.983	.064	72	17.012	16.985	.027
130	17.046	16.983	.063	70	17.012	16.985	.027
129	17.046	16.983	.063	68	17.011	16.985	.026
128	17.047	16.983	.064	66	17.011	16.985	.026
127	17.046	16.983	.063	64	17.011	16.985	.026
126	17.046	16.983	.063	62	17.010	16.985	.025
125	17.044	16.983	.061	60	17.009	16.985	.024
124	17.041	16.983	.058	58	17.011	16.985	.026
123	17.038	16.983	.055	56	17.009	16.985	.024
122	17.032	16.983	.049	54	17.009	16.985	.024
121	17.027	16.983	.044	52	17.009	16.985	.024
120	17.025	16.983	.042	50	17.009	16.985	.024
119	17.024	16.983	.041	48	17.009	16.985	.024
118	17.023	16.983	.040	46	17.009	16.985	.024
117	17.023	16.983	.040	44	17.010	16.985	.025
116	17.024	16.983	.041	42	17.010	16.985	.025
115	17.026	16.984	.042	40	17.009	16.985	.024
114	17.025	16.984	.041	38	17.009	16.985	.024
113	17.027	16.984	.043	36	17.009	16.985	.024
112	17.028	16.984	.044	34	17.009	16.985	.024
111	17.028	16.984	.044	32	17.009	16.985	.024
110	17.026	16.984	.042	30	17.010	16.986	.024
109	17.025	16.984	.041	28	17.010	16.986	.024
108	17.024	16.984	.040	26	17.009	16.986	.023
107	17.022	16.984	.038	24	17.010	16.986	.024
106	17.021	16.984	.037	22	17.010	16.986	.024
105	17.019	16.984	.035	20	17.010	16.986	.024
104	17.017	16.984	.033	18	17.011	16.986	.025
103	17.017	16.984	.033	16	17.010	16.986	.024
102	17.015	16.984	.035	14	17.010	16.986	.024
101	17.014	16.984	.030	12	17.010	16.986	.024
100	17.014	16.984	.030	10	17.009	16.986	.023

PLATE I.



Accompanying Appendix R[1], 1878

APPENDIX R 2.

CONSTRUCTION REPORT OF AN 8-INCH MUZZLE-LOADING RIFLE CONVERTED FROM A 10-INCH RODMAN SMOOTH-BORE, BY LINING—BY BREECH INSERTION—WITH A COILED WROUGHT-IRON TUBE, HAVING A JACKET SHRUNK ON EXTENDING THROUGH THE BREECH.

(One plate.)

PRELIMINARY REMARKS.

The difficulties of securing perfect weldings in coiled wrought-iron tubes have led in some instances—in the history of the employment of linings constructed in the manner and on the present plan of muzzle insertion—to the development of grave accidents in service; tubes being blown out and the muzzles torn off, all from defective welds.

The most satisfactory and secure remedy for this imperfection undoubtedly lies in the provision of a shoulder on the tube (in front of the charge), the gun being recessed for its reception.

An otherwise strong and durable construction embodying this feature must accordingly have an important advantage over the present plan of muzzle insertion, in which no adequate provision can be made to prevent the destructive effects of a tube being blown out. This accident is likely to occur if all the welds are not sound—a perfection which it is impossible, from the nature of the construction of coiled wrought-iron tubes, to uniformly and certainly attain.

The uniform success of our present guns is, in a great measure, due to excellence of work and care in manufacture; but it is evident that a decided improvement attains, if we can have perfect immunity from the defect alluded to above, while securing a perfectly reliable construction in other respects.

A consideration of the question has led to the construction of a gun on an improved plan of breech insertion, having, it is believed, more durability than the present plan of muzzle insertion, and securing the other advantages above quoted.

The imperfections of breech insertion, in alterations heretofore made, have arisen from the mode of construction employed, to wit, *separating* the breech-plug from the strengthening tube shrunk on the inner tube or lining; also from the solid construction of the plug.

The throwing of the entire longitudinal strain on to a breech-plug by depriving it of all assistance from the longitudinal strength of the enveloping jacket, produces a line of longitudinal weakness at the junction of the tube and plug, where the longitudinal and tangential strains, under fire, combine to produce rupture. This fact is well established by experiments in England.

In the construction under consideration, the jacket is shrunk on the tube, and extends continuously with a uniform thickness from a point a short distance in front of the trunnions to the breech-cup of the inner tube, and thence, with an increased thickness, *clear through the breech to its face.*

This unbroken continuity, and the yielding hollow wrought-iron breech thus formed, give all the strength desirable at the bottom of the bore, to resist the combined longitudinal and tangential strains at that point; and the breech portion of the jacket by its hollow form being permitted

to expand in unison with the tube when the latter is distended under the strains of discharge, avoids the danger of rupture liable to result from the rigidity of a solid, unyielding breech. A square-cut plus thread cut on the breech portion of the jacket corresponds with a minus thread cut on the cast iron, each to form the union of one with the other. The area of cross-section of the wrought iron is such as to have its strength proportional to the strength of the thread on the cast iron; reference being had to the relative strengths of the two metals.

The breech portion of the jacket, it will be observed, is so constructed as to overlap the bottom of the tube and the exterior portion of its cup. The longitudinal thrust consequently is, at this point, principally borne by the wrought-iron jacket, and not by the secondary breech-plug, simply used to close the hollow part of the former. By these arrangements, the greatest resistance is secured to longitudinal strains.

A breech plug of cast iron completes the construction of the breech. The inner tube, *shouldered* and closed at the bottom in the usual manner, completes the mention of the general features of the construction.

It will be seen that the jacket (1″.5 thick) extends to the front, a distance of about 40 inches from the bottom of the bore, thus reinforcing the inner tube (1″.25 thick) to a greater length than in the case of the "B" tubes of the present constructions, and consequently fully strengthening it over all the space where the pressures are at all dangerous.

DESCRIPTION OF THE GUN.

Plate 1, Fig. 1, represents a 10-inch Rodman smooth-bore gun with its lining inserted from the breech. Fig. 2 is a transverse section in the plane *a*, *b*. Fig. 3 is a similar section in the plane *c*, *d*. Fig. 4 is a longitudinal section in the plane *e*, *f*.

Fig. 4. The gun is essentially composed of three parts: (A) the original 10-inch smooth-bore, bored out to receive the lining; (B) a lining-tube of coiled wrought iron (welded), with a jacket (C) of wrought iron with its hollow base or plug extending to the face of the breech; and the breech-screw (D). The bottom of the tube is closed by a wrought-iron base or cup (E). A shoulder, *h*, *h*, on the inner tube, prevents the tube from being thrust forward by the effects of repeated firings, or blown out from imperfect coil-welds. A screw-collar, *k*, at the muzzle, gives additional security, resisting any forward thrust of the metal of the tube in front of the shoulders. The dimensions of the finished bore of the cast-iron body, and the exterior dimensions of the wrought-iron tube, are given in Table 1.

It will be seen that the play between the cast-iron body and tube and jacket does not exceed 0″.01 for a length of 88″ from the muzzle, nor 0″.004 from this point to the commencement of the screw-thread.

The greatest diameter of the tube and jacket is 14″.7. The diameter of the tube from the muzzle-collar to the first shoulder is 10″.5. The maximum thickness of the tube and jacket is therefore 3.″35, and the minimum thickness of the tube is 1″.25.

The curved part of the end of the tube is described with a larger radius than the corresponding curve in the cast iron, so as not to be in contact with it at that part. This space prevents the tube from acting as a wedge to split open the cast iron.

The thread upon the muzzle-collar slightly exceeds in length that of the corresponding thread in the muzzle of the casing, so as to insure a close contact between the end of the tube and the bottom of the bore of the casing.

RIFLING.

The rifling of the gun consists of 15 lands and grooves each, of equal width.

Width of lands and grooves .... 0.8377 inch.
Depth of grooves .... 0.075 inch.
Twist uniform, one turn in 40 feet.

The rifling stops at a point 10 inches from the bottom of the bore, and the diameter of the unrifled portion of the bore is equal to that of the rifled portion across lands.

VENTING.

The old vent was closed (the copper bushing having been removed) by a wrought-iron screw-plug, and 2″.75 nearer the muzzle a new one was bored, parallel to the vertical plane through the axis of the bore, and distant therefrom 2″.50. The axis of the vent enters the bore at 3″.5 from the bottom.

FABRICATION OF THE GUN.

The tube was manufactured and work of conversion performed at the West Point Foundery.

The gun selected for the conversion was 10-inch Rodman gun No. 16, manufactured at the South Boston Foundery, and inspected and proved in 1865.

The mechanical tests of the metal employed gave the following results:

Density 7.223
Tenacity, pounds per square inch 31,315

The tube was made of 2″.25 coiled Ulster tube-iron; the jacket of coiled Ulster tube-iron 4″.00 by 3″.35, and its rear section of a forging from scrap of the same iron; the breech-plug of gun-metal.

The following results were obtained by mechanical tests of the iron used. The specimens of the bar-iron were taken from the bar and with the fiber.

Specimens.		Area of cross-section.	Density.	Tenacity.	Elongation per inch at rupture.
		Inches.		*Pounds.*	*Inches.*
1. From 2″.5 bar	Tube	0.19635	....	51,925	0.280
2. From 2″.5 bar	Tube	0.19635	....	46,855	0.2525
3. From 4″.00 × 3″.35 bar	Coiled sections of jacket	0.1963	....	46,855	0.300
4. From 4″.00 × 3″.35 bar	Coiled sections of jacket	0.1971	....	48,698	0.3168
5. Taken from solid forging, rear sections of jacket		0.19635	....	49,402	0.2626
6. Taken from casting, breech-plug		1.112	7.3426	29,221	....

The tube was made in the usual manner in four sections. The jacket was made in three sections, the rear one from the solid forging. When prepared for welding, the rear section was 22″.5 long and bored to 6″; the middle section 31″ long, and bored for one-half its length to 6″, for the other (the front) half to 9″.5; the front section was 32″ long and bored to 9″.5. After welding, the jacket was cut to a length of about 60″, in such manner as to throw the joint between the forged and coiled sections at a distance of 49″.25 from the front of the jacket.

After the tube had been bored out, fitted with a breech-cup, and

turned down to receive the jacket, and the latter bored to a diameter about 0''.005 less than the corresponding diameter of the tube and rough-turned to a diameter slightly in excess of its greatest finished dimensions, both were proved with water (120 pounds to the square inch). The jacket was left about $\frac{1}{8}$ inch shorter than the tube where turned down to receive it, to insure contact between the base of the tube and the corresponding shoulder of the jacket when united by shrinking.

To prevent the jacket from turning upon the tube during the operation of screwing the two into the threads prepared for them in the casing, two dowels were screwed into the base of the tube, which were designed to fit into corresponding recesses in the shoulder of the jacket. To insure this fit, which must be accomplished during the operation of shrinking, the screw-threads for the dowels in the base of the tube were tapped through holes, in a steel templet, which was so shaped on its two faces as to fit the base of the tube and the face of the shoulder of the jacket. The recesses in the jacket were then bored through the same holes in the same templet.

The jacket was then shrunk on to the tube, and after cooling, the forward joint between the two was found to be closed to within 0.03 of an inch. The joint was subsequently closed on the exterior, by crowding into it metal from a lip left for the purpose on the tube.

The exteriors of the tube and jacket were then turned to diameters as nearly approaching those of the larger and smaller portions of the cast-iron body as was compatible with their insertion by mechanical means, and a screw-thread was cut upon the base of the jacket to correspond to that cut in the breech of the casing.

The tube and jacket, as a whole, were then inserted, forced down in the casing, and screwed home into position by means of levers, after which the muzzle-collar was screwed in and the steel pin inserted.

Table No. 1 shows the relative diameters of the tube and jacket and of the bore of the casing.

INSPECTION.

Careful inspections were made of every detail incident to the construction, and the gun, after completion, finally inspected, accepted as satisfactory, and shipped to Sandy Hook for powder-proof.

PRINCIPAL DIMENSIONS.

Length of bore	120	inches.
Length of tube	120	inches.
Length of jacket over tube	43	inches.
Total length of finished tube	136.66	inches.
Interior diameter of jacket	10.50	inches.
Exterior diameter of tube under jacket	10.507	inches.
Diameter of finished tube from screw-thread to first shoulder	14.712	inches.
Corresponding diameter of bore of casing	14.714	inches.
Diameter of finished tube from first shoulder to second shoulder	13.494	inches.
Corresponding diameter of bore of casing	13.498	inches.
Diameter of finished tube from second shoulder to third shoulder	11.489	inches.
Corresponding diameter of bore of casing	11.494	inches.
Diameter of finished tube from third shoulder to neck	10.489	inches.
Corresponding diameter of bore of casing	10.495	inches.
Number of lands and grooves	15	
Width of lands and grooves	0.83776	inch.
Depth of grooves	.075	inch.
Twist uniform, one turn in 40 feet.		
Weight of gun	16,020	pounds.
Counter-preponderance	189	pounds.

TABLE No. 1.

Relative diameters of bore of cast-iron body of 10-inch gun and wrought-iron tube for insertion therein at different points of the cylindrical length.

Inches from face of muzzle.	Interior diameter of bore.	Exterior diameter of tube.	Difference.	Inches from face of muzzle.	Interior diameter of bore.	Exterior diameter of tube.	Difference.
	″	″	″		″	″	″
6	10.500	10.490	0.010	81	13.504	13.495	.009
8	10.500	10.490	.010	82	13.500	13.495	.005
10	10.500	10.490	.010	83	13.501	13.495	.006
12	10.500	10.490	.010	84	13.501	13.495	.006
14	10.500	10.490	.010	85	13.501	13.495	.006
16	10.500	10.490	.010	86	13.501	13.495	.006
18	10.500	10.490	.010	87	13.500	13.495	.005
20	10.499	10.490	.009	88	13.500	13.495	.005
22	10.497	10.489	.008	89	13.499	13.495	.004
24	10.496	10.489	.007	90	13.499	13.496	.003
26	10.495	10.488	.007	91	13.498	13.494	.004
28	10.495	10.489	.006	92	13.498	13.494	.004
30	10.496	10.489	.007	93	13.498	13.494	.004
32	10.494	10.489	.005	94	13.498	13.494	.004
34	10.495	10.489	.006	95	13.498	13.494	.004
36	10.495	10.489	.006	96	13.498	13.494	.004
38	10.495	10.489	.006	97	13.498	13.494	.004
40	10.495	10.488	.007	98	13.498	13.494	.004
42	10.495	10.489	.006	99	13.498	13.494	.004
44	10.495	10.489	.006	100	13.498	13.494	.004
46	10.495	10.489	.006	101	13.498	13.494	.004
48	10.495	10.489	.006	102	13.498	13.494	.004
50	10.495	10.489	.006	103	13.498	13.494	.064
52	10.495	10.489	.006	104	13.497	13.494	.003
54	10.496	10.489	.007	105	13.497	13.494	.003
56	10.495	10.490	.005	106	13.497	13.494	.003
58	10.495	10.490	.005	107	13.497	13.495	.002
60	10.495	10.490	.005	108	13.497	13.495	.002
62	10.496	10.490	.006	109	13.497	13.495	.002
64	10.496	10.490	.006	110	13.497	13.495	.002
66	10.496	10.490	.006	111	13.497	13.495	.002
68	10.495	10.490	0.005	112	13.497	13.494	.003
				113	13.497	13.496	.001
69	11.494	11.489	0.005	114	13.497	13.496	0.001
70	11.494	11.489	.005				
71	11.494	11.489	.005	115	14.712	14.712	0.000
72	11.494	11.489	.005	116	14.712	14.712	.000
73	11.493	11.489	.004	117	14.712	14.712	.000
74	11.494	11.488	.006	118	14.712	14.712	.000
75	11.494	11.489	.005	119	14.713	14.712	.001
76	11.494	11.489	.005	120	14.714	14.712	.002
77	11.494	11.488	0.006	121	14.714	14.711	.003
				122	14.714	14.712	.002
80	13.508	13.495	0.013	123	14.714	14.707	0.007

8 INCH M.L. RIFLE.

Converted from a 10 inch Rodman smooth bore, by lining with a jacketed, coiled wrought-iron tube, inserted from the breech.

Fig. 2.

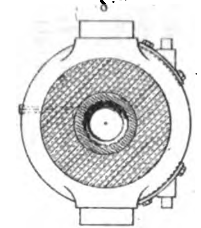


Fig. 1.

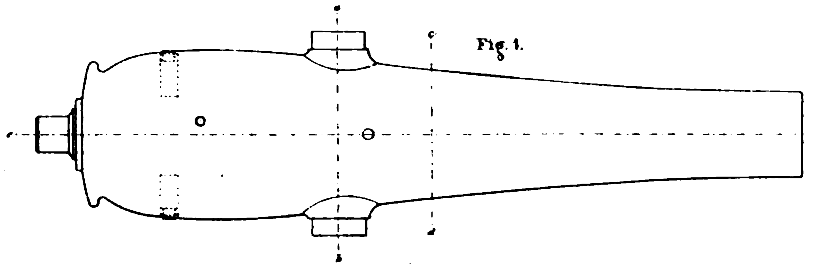


Fig. 3.

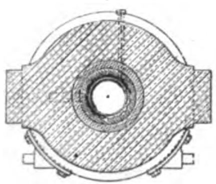
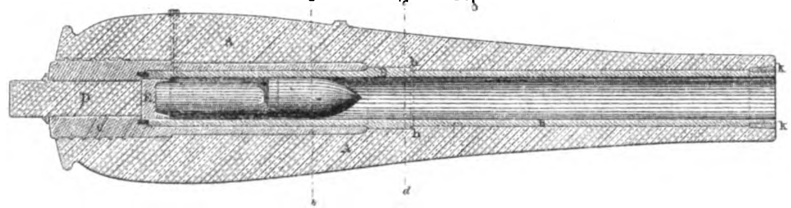


Fig. 4.



RIFLING.

Twist uniform one turn in 40 feet.
15 Grooves and Lands each 0.83776 in wide
Grooves 0.075 in deep.
" Filleted with a rad. of 0.02 in
Lands beveled " " " " 0.01 "
Rifling begins 10 inches from bottom of bore.
Weight of Gun 16020 lbs. Preponderance 189 lbs.

Scale.

10 20 30 40 50 inches.

T. Crispin
Bvt. Col. U.S.A. Lt Col of Ordnance
Constructor of Ordnance

APPENDIX R 3.

CONSTRUCTION REPORT OF AN 8-INCH BREECH-LOADING RIFLE, CONVERTED FROM A 10-INCH RODMAN SMOOTH-BORE BY LINING WITH A STEEL-JACKETED, COILED, WROUGHT-IRON TUBE, INSERTED FROM THE BREECH, JACKET OF THE TUBE BEING PROLONGED TO THE REAR AND ADAPTED FOR RECEPTION OF THE ROUND WEDGE FERMETURE.

(Five plates.)

PRELIMINARY REMARKS.

The Board on Heavy Rifled Ordnance instituted by the War Department under the act of Congress of June 6, 1872, for the selection of breech-loading and muzzle-loading rifled ordnance for experiments and tests, in submitting its recommendations, designated, among others, a Krupp breech-loading system for procurement by the United States, placing it, among breech-loaders, first on the list in order of merit.

The recommendations of the board were only carried out at the time, as far as breech-loading guns were concerned, by the fabrication of the Thompson and Sutcliffe rifles, which latter now await the appropriation of funds by Congress for the prosecution of experiments with them.

The test of a system embodying the round-wedge fermeture (Krupp pattern) as a breech mechanism, was delayed at the time (other systems taking precedence), and the department was only able, during the last year, to undertake and cause to be fabricated as a conversion, an 8-inch breech-loading rifle (with round-wedge fermeture), by the alteration of a 10-inch smooth-bore, and thus practically carry into effect the recommendation of the Board on Heavy Ordnance of 1872, looking to the test of a system of breech-loading regarded by it as promising superior results to all others presented for its consideration and action.

The details of the breech mechanism being well known, the main question was to devise a system of gun construction, involving the utilization of a cast-iron gun and combining with it a steel breech-piece inserted at the rear, furnishing a strong and proper support for the breech-block, and providing an aperture to receive and work in it the latter.

The longitudinal weakness (for want of metal) which would evidently attain if we attempted to form an aperture in the breech of a cast-iron gun to receive the breech fermeture; also the inherent weakness of cast iron to stand the strains and jar of firings; also the material shortening of the bore which would result, conclusively led, with other considerations in the planning of this conversion, to the use of a steel breech-piece *extending beyond and to the rear of the cast-iron body, sufficient to receive and work in it a well-proportioned and sufficiently strong fermeture.*

The important question of solidly uniting the steel receiver of the fermeture with the cast-iron body, received attentive consideration. It was decided that a screw-thread of the same form, pitch, and dimensions as that employed in the case of the 8-inch muzzle-loader breech insertion would (both from our calculations and the successful results attained with the latter gun) give all the solidity and strength that could possibly be brought into requisition in service.

To insure no possibility of the cast iron rupturing from the longitudinal strains, the screw-thread, it was determined, should be placed upon

the front part or jacket portion of the breech-receiver. This extension not only affords a place for the thread, but also gives additional tangential strength to the system by supporting the wrought iron coiled-tube, forming the interior lining of the gun. The tube is further tangentially supported by that portion of the breech-receiver rearward of the jacket portion which finds place in the cast-iron body, and extends far enough into the breech to nearly or quite envelop the charge-chamber and seat of the shot; thus affording a strength more than adequate to resist the great strains which must be sustained by this portion of the gun. The enlargements (rearward of jacket portion) in diameters of the breech-receiver piece also provide sufficient metal to resist the longitudinal and jarring strains to which the protruding walls of the breech-piece are subjected at the point where it protrudes from the cast-iron body. The protruding portion, it will be seen, is so dimensioned as to accommodate the fermeture, and have all the requisite strength for its functions.

The bore tube, it was decided, should be made of coiled wrought iron on account of the decided success heretofore attained by us in lining guns with coiled tubes constructed of this metal.

The tube is shouldered to prevent any forward movement of the tube, either from the pressure developed at the seat of the gas-check, or the strains resulting from the thrust of the projectile developed by the friction between the walls of the gun and the shot in firing.

A steel band it was deemed advisable should be shrunk on to the cast-iron body at its breech end, to give additional tangential strenth to the system, and also to give a better finish and appearance to the gun.

SUMMARY.

In this construction, the question of the strength of the system to withstand the different strains which it will be subjected to in service, it is thought, has been fully met. The coiled wrought iron as an interior lining tube secures all the strength and extensibility requisite to withstand the tangential strains developed at the surface of the bore, using the heaviest battering charges for the caliber employed, and the durability of the surface of the bore and the rifling—using expanding systems of projectile—have been fully proved. The disabilities likely to arise from defective coiled welds are also fully met by shouldering the tube.

The use of a steel breech-piece secures all the necessary strength, in providing for the reception and working of a practical and thoroughly digested and tested system of breech machanism, and also essentailly and materially adds by its extension into the body of the cast iron—enveloping the wrought-iron tube beyond the space of dangerous pressures—to the tangential strength of the system. The cast-iron body playing a secondary part, as its inferior strength demands, finds its interior surfaces so placed or distanced with reference to the strains developed at and along the bore as to be far within their capacities for endurance, and its thickness of walls gives all the necessary additional strength required to complete the system of construction, save, perhaps, the reinforce afforded by the steel band at the seat of the charge.

The utilization of cast-iron, it is believed, will *materially* diminish the expense of breech-loading cannon of heavy calibers, using the round wedge fermeture, now so costly in their fabrication, and will enable us to secure, and within the mechanical resources of our own country, desirable and necessary breech-loading armaments of all desirable calibers, for

our coast defenses at moderate outlays, and having all the essential features of durability and strength found in the more expensive system of the same kind now used by most of the principal (continental) powers of Europe.

A full and special description of the gun, as actually made, will be found embodied below in this report.

DESCRIPTION.

Plate I, Fig. 2, C is the cast-iron casing, which consists of a 10-inch Rodman smooth-bore gun, cut off at the breech to a length of 123.25 inches, and bored up to the requisite diameters to receive the tube A with its jacket B, which is inserted at the breech.

The tube is made of coiled wrought iron and is of equal length with the casing. It is re-enforced at the breech end for a distance of 40 inches by a steel jacket, which is united with it by shrinkage. The breech of the jacket is prolonged 24 inches to the rear of the casing and tube, and is fitted for the reception of the mechanism of the breech fermeture.

The united jacket and tube are inserted in the casing with a shrinkage of 0.006 inch over the jacket, while the tube in front has a play of about the same amount. They are held in position by the thread *a a* and the muzzle-collar *b*, also the shoulder *c c*.

The breech of the casing is re-enforced by the steel breech-band D, which is put on under a shrinkage of 0″.03 and secured by the pin *h*.

The breech mechanism works in a slot cut in the prolongation of the steel jacket to the rear of the casing and tube, and is, in all its essential features, the same as that used in the Krupp breech-loading guns of heavy caliber.

The steel breech-block E is constructed on the sliding wedge system, and is cylindro-prismatic in form. The front face of the block is perpendicular to the axis of the bore, while the rear or cylindrical portion is inclined 1° 15′. The movement is regulated by the two guides *g g* in the slot, which work in corresponding grooves in the block, and are constructed parallel to the axis of its cylindrical portion.

The front of the block is hollowed out for the reception of a hardened disk *c*, called the obturator-plate. This plate, when the breech is closed, abuts against the gas-check *f f*, which consists of a Broadwell ring inserted in a recess at the rear of the tube.

Plate II.—The breech-block is fitted to receive the different pieces of mechanism required for working it. These consist of the locking-plate *a*, the translating screw *b*, and the locking-screw *c*, with its nut *d*. The locking-plate is attached by screws to the left side of the breech-block. The translating screw is located in a longitudinal groove in the upper surface of the block, and is secured in position by bearings at each end. It works in the half nut *e* which is attached to the breech-receiver by a screw.

The locking-screw and its nut are located in a cylindrical recess at the rear of the block and next to the locking-plate. The neck of the screw passes through and turns in a hole in the locking-plate, and the opposite end in a recess in the breech-block. The nut is made about one-half an inch shorter than the recess, which allows it a motion of translation along the screw for that distance. At the end of the nut next to the locking-plate is attached a stud, which limits its rotary motion with the screw to one-third of a turn. On the exterior surface of the nut are four rings or circular threads; the one next to the locking-plate is complete,

while the others are partially sheared off. When the breech is nearly closed the sheared threads lock into the indentations *g g g*, and the complete one enters the recess *f*. In withdrawing the block the sheared portion of the nut is brought to the rear.

The two screws are worked in turn by the lever-wrench C.

To close the breech, the wrench is placed upon the head of the translating-screw and the block run in until the uncut thread of the locking-nut comes to a bearing in its recess, and brings the movement to a stop. The wrench is then shifted to the locking-screw; for one-third of a turn the screw and nut turn together, and the partially-sheared threads of the nut lock into their corresponding recesses on the breech-receiver. The movement of the nut is then stopped by its stud, while the movement of the screw continues, and by bringing the threads of the nut to a firm bearing on the faces of their recesses on the breech-receiver forces the block into the slot until it is firmly wedged, and the breech thus fully closed.

To open the breech the locking-screw is turned in the opposite direction, and by carrying the nut with it for one-third of a turn the unlocking is effected. The nut is brought to a stop by the stud, as before, the uncut thread comes to a bearing against the face of its recess, and the block is drawn out until the nut is reached by the end of the screw. The remainder of the movement is then effected by the translating-screw.

The outward movement of the block is limited by the chain *h* (Plate 1, Fig. 3).

Plate III shows side elevation of gun (breech closed ready for firing), and plan of gun (breech open ready for loading).

RIFLING, CHAMBERING, AND VENTING.

The gun is rifled with fifteen lands and grooves each, of equal width. The lands are connected with the chamber by a bevel 1″.5 in length.

Depth of rifling	0.075 inch.
Width of lands and grooves	0.83776 inch.
Twist uniform, one turn in 40 feet.	

The chamber is 22 inches in length, and equal in diameter to the bore across the grooves. It has a capacity for a maximum charge of 35 pounds of powder.

The vent is located in the breech-block, in such a position as to be in the axis of the bore when the breech is closed.

FABRICATION.

The work of conversion was performed at the South Boston Foundery. The gun selected for the casing was a 10-inch Rodman smooth-bore gun No. 11, made at the same foundery, and inspected and proved in 1864.

The density and tenacity of the metal were as follows:

Density	7.245
Tenacity	34,359 pounds.

The wrought-iron tube was manufactured at the West Point Foundery, from Ulster tube-iron, 4″ by 3″.35. It was made in four sections, which were butt-welded together by the process usually employed at that foundery, then bored to 8″, turned to an exterior diameter, slightly in excess of that required, and subjected to a water-test of 120 pounds to the square inch.

Specimens of the iron used were tested with the following results:

Density	7.6550
Tenacity	48,010 pounds.

The jacket, breech-block, and breech-band were manufactured at the works of Sir Joseph Whitworth & Co., at Manchester, England, and are made of "fluid compressed steel."

This metal is subjected, while in a liquid state, to a heavy pressure, for the purpose of expelling air-bubbles, and is afterwards reheated and hammered to secure uniformity and regularity of structure. Thorough tests of the physical properties of this metal were made from specimens supplied from Whitworth's works, together with others taken from the jacket. The results are given in the record hereto appended.

Specimens taken from the jacket were tested for density and tenacity, with the following results:

Specimen.	Density.	Area of broken section.	Tenacity per square inch.	Where tested.
		Inch.	*Pounds.*	
No. 1	7.8491	0.33592	118,480	United States ordnance agency, New York.
No. 2	7.8568	0.33490	91,370	Do.

To prepare the casing for the reception of the tube and jacket, it was bored up to 11 inches, recessed for the muzzle-collar, and cut off at the breech to the required length. It was then counter-bored from the breech to the following diameters, viz: for 56 inches to 12 inches; for 40 inches to 16 inches; for 18 inches to 16.825 inches; for 13.5 inches to 20 inches; for 3.5 inches to 22 inches.

The end of each counter-bore was rounded off to form a suitable shoulder, and a thread for the jacket, 0.4 inch depth, was cut upon the 16-inch diameter. The exterior was then turned down at the breech for putting on the steel breech-band.

The interior of the jacket was bored up to the required diameters, and the slot for the breech mechanism drilled out and finished by boring and planing. The tube, meanwhile, was chambered, rifled, recessed for the gas-check, and the exterior turned down at the breech end to an average diameter 0''.003 in excess of that of the interior of the jacket. The jacket and tube were then shrunk together by heating up the jacket until the interior was sufficiently expanded to receive the tube, which was lowered in by means of a crane.

The exterior of the jacketed tube was next turned down to the diameters given in table No. 2.

In order to provide for the longitudinal expansion of the casing, which would take place in heating it up for the insertion of the jacketed tube, the shoulders upon the jacket were finished so as to allow a clearance large enough to obviate any danger of contact with the casing before a bearing was effected at the shoulder on the wrought-iron tube. The screw-thread was turned with a clearance of 0''.02 on the outer surface, and 0''.12 on the surface opposite the one of contact with the casing.

The breech-block, with its attachments, was finished in the mean time, and fitted into the slot prepared for its reception.

The breech-band was bored, turned, and made ready for shrinking on to the casing.

INSERTION OF THE TUBE, ETC.

The casing, jacketed tube, and breech-band, being ready for uniting by shrinkage, one of the pits used in the casting of heavy guns was arranged for heating the casing by placing four furnaces, with a capacity of about 400 pounds of coal each, at equal intervals around the wall. These furnaces rested on cast-iron pillars, which raised them about four feet from the bottom.

Two flues were provided for furnishing air to the furnaces, one on either side of the pit, with branches at the bottom so that the air could be delivered directly under the furnace-grates, while near the top of the pit an opening was made and connected with a chimney and a damper inserted in the opening, by means of which the draught could be regulated.

To form a support for the casing, two sections of gun-flask were placed one above the other in the center of the pit, and the upper one covered with a thick cast-iron plate; upon this plate, a hollow cast-iron cylinder of suitable dimensions was placed to form a rest for the muzzle of the casing. The casing was placed breech upward in the pit, the muzzle resting on the cylinder, and was securely braced at the trunnions.

In this position, the breech of the casing was almost flush with the top of the pit, which was covered with a large plate of boiler-iron. In the center of this plate was a circular hole for the insertion of the tube.

A moderate fire was kindled in the furnaces about 48 hours before the contemplated time of insertion, for the purpose of drying the pit, which had become quite damp from long disuse. About 40 hours after kindling, the fires were replenished to the full capacity of the furnaces.

The jacketed tube, meanwhile, was prepared for insertion. Water-caps were fitted into both ends of the wrought-iron tube. The one inserted at the breech was provided with inlet and outlet pipes for attaching hose, for the purpose of turning on a current of cold water in case that a withdrawal should become necessary. A cast-iron "spider," or ring with handspike-sockets on the exterior, was secured to the breech of the jacket, for screwing it into the casing.

The temperature of the casing was taken at various intervals and the diameter of its bore measured. About half an hour before the insertion was attempted, the temperature was found to be 633°, while the maximum diameter of the bore had increased from 22.005 inches to 22.09 inches. The length of the casing from the breech to the forward shoulder in the bore was found at the same time to have increased from 55.98 inches to 56.22 inches.

The diametrical expansion of the casing now being considered sufficient to effect the insertion of the tube, the latter, filled with cold water, was lowered by a crane into the bore of the casing until the threads came in contact. Handspikes were then placed in the sockets of the "spider" and the tube rapidly screwed home. The entire operation of insertion was accomplished without difficulty and occupied only eight minutes.

The covers were now removed from the pit, the fires in the furnaces extinguished, and a stream of water was turned upon the gun to hasten the cooling. When it had returned to nearly its normal temperature, the breech-band was inclosed in a sheet-iron cylinder, and heated by a wood fire until its diameter had increased about 0.06 inch. It was then raised with a crane by means of hooks which clasped its forward end, swung round until directly over the gun, and lowered to its place upon the breech of the casing. It was then cooled by a stream of water, and a hole was bored for the securing-pin, which was inserted in its place.

The gun was then removed from the pit, the muzzle-collar was fitted and screwed home, and the muzzle faced and finished in a lathe.

This substantially completed the fabrication of the gun.

INSPECTION.

The workmanship and finish of the gun were good in every respect.

PRINCIPAL DIMENSIONS.

Total length of gun	147.25	inches.
Length of cast-iron casing	123.25	inches.

Length of wrought-iron tube	123.25	inches.
Length of steel jacket	64	inches.
Length of breech-band	15	inches.
Exterior diameter of breech-band { maximum	35.70	inches.
Exterior diameter of breech-band { minimum	35.05	inches.
Interior diameter of breech-band	30.97	inches.
Exterior diameter of casing under breech-band	30.99	inches.
Length of neck of tube	5.50	inches.
Length of muzzle-collar	5.50	inches.
Diameter of neck of tube	9.94	inches.
Interior diameter for muzzle-collar	9.948	inches.
Length of recess for muzzle-collar	6	inches.
Diameter of recess for muzzle-collar	11.765	inches.
Diameter of muzzle-collar across threads	11.755	inches.
Length of rifled portion of bore, including bevel	101.25	inches.
Length of chamber	22	inches.
Diameter of bore across lands	8.00	inches.
Diameter of chamber	8.15	inches.
Width of lands	0.83776	inch.
Width of grooves	0.83776	inch.
Depth of rifling	0.075	inch.
Twist of rifling, one turn in	40	feet.
Length of breech-block	23.5	feet.
Width of breech-block	10	feet.
Thickness through center	13.5	feet.
Width of slot for breech-block	10.05	feet.
Length of translating-screw	25.5	feet.
Diameter of translating-screw across threads	1.5	feet.
Length of locking-screw	10.7	feet.
Diameter across threads	2.75	feet.
Length of locking-nut	5.75	feet.
Diameter across uncut thread	5.75	feet.
Weight of gun	17,075	pounds.
Preponderance	420	pounds.

The gun, when finished, was sent to the proving-ground at Sandy Hook, N. J., for trial.

TABLE No. 1.

Relative diameters of the interior of the steel jacket and that portion of the wrought-iron tube over which it was shrunk, 8-inch breech-loading converted rifle.

Inches from front end of jacket.	Interior diameter of jacket.	Exterior diameter of tube.	Difference.	Inches from front end of jacket.	Interior diameter of jacket.	Exterior diameter of tube.	Difference.
	"	"	"		"	"	"
39	12.038	12.040	0.002	19	12.043	12.046	0.003
38	12.040	12.043	.003	18	12.042	12.046	.004
37	12.042	12.043	.001	17	12.043	12.046	.003
36	12.043	12.044	.001	16	12.043	12.046	.003
35	12.043	12.044	.001	15	12.043	12.046	.003
34	12.043	12.046	.003	14	12.043	12.046	.003
33	12.043	12.046	.003	13	12.043	12.046	.003
32	12.043	12.046	.003	12	12.043	12.046	.003
31	12.043	12.046	.003	11	12.043	12.046	.003
30	12.043	12.046	.003	10	12.043	12.046	.003
29	12.043	12.046	.003	9	12.044	12.046	.002
28	12.043	12.046	.003	8	12.044	12.046	.002
27	12.043	12.046	.003	7	12.044	12.046	.002
26	12.043	12.046	.003	6	12.045	12.046	.001
25	12.042	12.046	.004	5	12.045	12.046	.001
24	12.042	12.046	.004	4	12.045	12.046	.001
23	12.043	12.046	.003	3	12.045	12.046	.001
22	12.042	12.046	.004	2	12.045	12.050	.005
21	12.042	12.046	.004	1	12.045	12.050	.005
20	12.040	12.046	.006				

Table No. 2.

Relative diameters of the interior of the cast-iron casing and exterior of the united tube and jacket for insertion therein, 8-inch breech-loading converted rifle.

Distance from muzzle.	Diameter of bore of casing.	Exterior diameter of tube.	Difference.	Distance from muzzle.	Diameter of bore of casing.	Exterior diameter of jacket.	Difference.
"	"	"		"	"		"
6	11.004	10.995	0.009	87	15.980	16.005	....
8	11.004	10.995	.009	88	15.994	16.005	....
10	11.004	10.995	.009	89	15.994	16.005	....
12	11.004	10.995	.009	90	15.994	16.005	....
14	11.003	10.995	.008	91	15.994	16.005	....
16	11.003	10.995	.008	92	15.994	16.005	....
18	11.003	10.995	.008	93	15.994	16.005	....
20	11.003	10.995	.008	94	15.994	16.005	....
22	11.003	10.995	.008	95	15.994	16.005	....
24	11.003	10.995	.008	96	15.994	16.005	....
26	11.003	10.995	.008	97	15.995	16.005	....
28	11.003	10.995	.008	98	15.995	16.005	....
30	11.003	10.995	.008	99	15.995	16.005	....
32	11.003	10.995	.008	100	15.995	16.005	....
34	11.003	10.995	.008	101	15.995	16.005	....
36	11.003	10.995	.008	102	15.995	16.005	....
38	11.003	10.995	.008	103	15.995	16.005	....
40	11.003	10.995	.008	104	15.995	16.005	....
42	11.003	10.995	.008				
44	11.003	10.995	.008	105	16.829	16.834	....
46	11.003	10.995	.008	106	16.827	16.834	....
48	11.003	10.995	.008	107	16.827	16.834	....
50	11.003	10.995	.008	108	16.827	16.834	....
52	11.003	10.995	.008	109	16.828	16.834	....
54	11.003	10.995	.008				
56	11.003	10.995	.008	110	20.002	20.012	....
58	11.002	10.995	.007	111	20.003	20.012	....
60	11.002	10.995	.007	112	20.005	20.012	....
62	11.002	10.995	.007	113	20.005	20.012	....
64	11.002	10.995	.007	114	20.005	20.012	....
66	11.001	10.995	.006	115	20.005	20.012	....
				116	20.005	20.012	....
68	11.985	11.979	0.006	117	20.005	20.012	....
69	11.989	11.979	.010	118	20.005	20.012	....
70	11.988	11.979	.009	119	20.005	20.012	....
71	11.989	11.979	.010				
72	11.989	11.979	.010	121	21.997	22.005	....
73	11.989	11.979	.010	122	21.997	22.005	....
74	11.989	11.979	.010	123	21.997	22.005	....
75	11.989	11.979	.010				
76	11.988	11.979	.009				
77	11.988	11.979	.009				
78	11.988	11.979	.009				
79	11.988	11.979	.009				
80	11.988	11.979	.009				
81	11.987	11.979	.008				
82	11.987	11.979	.008				
83	11.987	11.979	.008				

APPENDIX R 4.

REPORT ON THE CARRIAGE ALTERED FOR THE 8-INCH BREECH-LOADING RIFLE.

(Two plates.)

The carriage altered from a 10-inch barbette carriage possesses the same general features in its modification as carriage No. 3, described in the Report of the Chief of Ordnance for 1877.

The same apparatus for elevating and depressing, consisting of toothed arcs attached to the gun and worked by pinions, is used; and a hydraulic buffer similarly attached between the chassis-rails checks the recoil. The rails are also provided with inclines or wedges and rubber hurters and counter hurters; but it differs from carriage No. 3 in the fact that no side catches are used to secure the gun "from battery" after recoil, consequently the gun after firing returns unaided "into battery," its position as a breech-loader for loading.

In other particulars the carriage differs from carriage No. 3 only in the following alteration, which has been applied to the front or pintle-transom.

The ordinary bolsters with the eccentric axle are replaced by two wrought-iron forks attached to and beneath the front of each chassis-rail, and to which is bolted the pintle-plate (Plate 2).

Each fork is made in two sections, one bolted to the inside and the other to the outside of the chassis-rail, and carries at the bottom a steel roller which rests upon the pintle bed-plate through a slot cut in the pintle-plate itself.

In the original carriage it was necessary to throw the chassis "in" and "out of gear" during the operation of "pointing," in order to secure rolling-friction to the system while traversing, and again sliding-friction when the piece was fired. This proved to be a serious imperfection, which the alteration described was designed to correct. It was first applied to carriage No. 3 (Report of the Chief of Ordnance, 1877), and thoroughly tested during the proof of 8-inch converted rifle No. 1, breech-insertion, and 8-inch converted rifle No. 5. Under all circumstances the carriage was easily and quickly traversed, and though various angles from $1\frac{1}{2}^\circ$ depression to 10° elevation were used during the firings, the forks and rollers were uninjured by the shock.

RECORD OF PRELIMINARY TESTS OF WHITWORTH'S FLUID-COMPRESSED STEEL.

APPENDIX I.

8-INCH BREECH-LOADING RIFLE.

Mean mechanical properties of Whitworth's fluid compressed steel.

	Specimen. Length.	Specimen. Area.	
	Inches.	*Sq. In.*	
Density	....	....	7.855
Tenacity	....	0.65	110,000 pounds.
Elastic limit under pulling stress			38,500 pounds.
Ultimate resistance to pulling stress			86,000 pounds.
Extension per inch at elastic limit	10	0.343	0.00230 inch.
Ultimate extension per inch			0.17500 inch.
Ultimate restoration per inch			0.00352 inch.
Ultimate permanent set per inch			0.17149 inch.
Elastic limit under thrusting stress			28,000 pounds.
Specimen began to bend at			42,000 pounds.
Compression per inch at elastic limit	10	1.000	0.00158 inch.
Compression per inch at 40,000 pounds			0.0049 inch.
Restoration per inch at 40,000 pounds			0.01630 inch.
Permanent set per inch at 40,000 pounds			0.0335 inch.
Hardness	....	....	16.230
Hardness of copper	....	....	5.000

SPECIMEN E, NO. I.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of section, acting upon a solid cylinder, 10 inches long (between shoulders) and 0″.662 in diameter, taken from a sample bar of fluid-compressed steel 6 inches square by 22 inches long, furnished by Sir Joseph Whitworth's Steel Works, Manchester, England.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	″	″	″	″	″	″
1,000	0.00009	0.00000	0.00009	0.00000	0.00000	0.00000
2,000	.00009	.00000	.00009	.00000	.00000	.00000
3,000	.00009	.00000	.00009	.00000	.00000	.00000
4,000	.00009	.00000	.00009	.00000	.00000	.00000
5,000	.00012	.00003	.00012	.00003	.00000	.00000
6,000	.00016	.00004	.00016	.00004	.00000	.00000
7,000	.00021	.00005	.00021	.00005	.00000	.00000
8,000	.00022	.00002	.00022	.00002	.00000	.00000
9,000	.00023	.00001	.00023	.00001	.00000	.00000
10,000	.00027	.00004	.00027	.00004	.00000	.00000
11,000	.00029	.00002	.00029	.00002	.00000	.00000
12,000	.00031	.00002	.00031	.00002	.00000	.00000
13,000	.00034	.00003	.00034	.00003	.00000	.00000
14,000	.00037	.00003	.00037	.00003	.00000	.00000
15,000	.00039	.00002	.00039	.00002	.00000	.00000
16,000	.00040	.00001	.00040	.00001	.00000	.00000
17,000	.00046	.00006	.00046	.00006	.00000	.00000
18,000	.00050	.00004	.00050	.00004	.00000	.00000
19,000	.00056	.00006	.00056	.00006	.00000	.00000
20,000	.00062	.00006	.00062	.00006	.00000	.00000
21,000	.00071	.00009	.00071	.00009	.00000	.00000
22,000	.00081	.00010	.00081	.00010	.00000	.00000
23,000	.00089	.00008	.00089	.00008	.00000	.00000
24,000	.00092	.00003	.00092	.00003	.00000	.00000
25,000	.00093	.00001	.00093	.00001	.00000	.00000
26,000	.00096	.00003	.00096	.00003	.00000	.00000
27,000	.00098	.00002	.00098	.00002	.00000	.00000

Specimen E, No. I—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	"	"	"	"	"	"
28,000	0.00100	0.00002	0.00100	0.00002	0.00000	0.00000
29,000	.00107	.00007	.00107	.00007	.00000	.00000
30,000	.00107	.00000	.00107	.00000	.00000	.00000
31,000	.00112	.00005	.00112	.00005	.00000	.00000
32,000	.00112	.00000	.00112	.00000	.00000	.00000
33,000	.00117	.00005	.00117	.00005	.00000	.00000
34,000	.00119	.00002	.00119	.00002	.00000	.00000
35,000	.00119	.00000	.00119	.00000	.00000	.00000
36,000	.00119	.00000	.00119	.00000	.00000	.00000
37,000	.00122	.00003	.00122	.00003	.00000	.00000
38,000	.00127	.00005	.00127	.00005	.00000	.00000
39,000	.00130	.00003	.00130	.00003	.00000	.00000
40,000	.00142	.00012	.00142	.00012	.00000	.00000
41,000	.00382	.00240	.00140	–.00002	.00242	.00242
42,000	.00547	.00165	.00155	+.00015	.00392	.00150
43,000	.00634	.00087	.00177	.00022	.00457	.00065
44,000	.00686	.00052	.00176	–.00001	.00510	.00053
45,000	.00762	.00076	.00167	–.00037	.00595	.00085
46,000	.00882	.00120	.00130	+.00050	.00750	.00155
47,000	.00962	.00080	.00180	–.00001	.00782	.00032
48,000	.01017	.00055	.00179	+.00041	.00838	.00056
49,000	.01087	.00050	.00220	.00005	.00857	.00029
50,000	.01197	.00110	.00225	–.00004	.00972	.00105
51,000	.01276	.00069	.00201	.00011	.01065	.00093
52,000	.01384	.00118	.00212	.00013	.01172	.00107
53,000	.01422	.00038	.00125	.00087	.01297	.00125
54,000	.01572	.00150	.00217	.00092	.01355	.00058
55,000	.01647	.00075	.00230	.00013	.01417	.00062
56,000	.01782	.00135	.00235	.00005	.01547	.00130
57,000	.01847	.00055	.00215	–.00020	.01632	.00085
58,000	.01967	.00120	.00225	+.00010	.01742	.00110
59,000	.02150	.00183	.00233	.00008	.01917	.00170
60,000	.02242	.00092	.00267	.00034	.01975	.00058
61,000	.02407	.00165	.00255	–.00012	.02152	.00179
62,000	.02547	.00140	.00307	.00052	.02240	.00088
63,000	.02697	.00150	.00285	–.00027	.02417	.00177
64,000	.02932	.00235	.00310	.00037	.02622	.00205
65,000	.03027	.00095	.00275	–.00035	.02732	.00110
66,000	.03152	.00125	.00270	–.00005	.02882	.00150
67,000	.03412	.00260	.00307	+.00037	.03105	.00223
68,000	.03602	.00190	.00300	–.00007	.03302	.00197
69,000	.03912	.00130	.00335	+.00035	.03577	.00275
70,000	.04112	.00200	.00355	.00020	.03757	.00280
71,000	.04433	.00321	.00299	–.00056	.04134	.00377
72,000	.04652	.00219	.00334	.00035	.04318	.00184
73,000	.05027	.00375	.00360	.00016	.04667	.00349
74,000	.05767	.00740	.00370	.00010	.05397	.00730
75,000	.06017	.00250	.00345	–.00025	.05672	.00275
76,000	.06212	.00195	.00378	+.00033	.05834	.00162
77,000	.06942	.00730	.00392	.00014	.06212	.00378
78,000	.07429	.00485	.00397	.00005	.07032	.00820
79,000	.07982	.00553	.00425	.00028	.07557	.00525
80,000	.08573	.00590	.00850	.00425	.07222	.00335
81,000	.09252	.00680	.00400	–.00450	.08852	.00630
82,000	.09942	.00690	.00438	+.00038	.09504	.00652
83,000	.11132	.01190	.00540	.00102	.10592	.01088
84,000	.12112	.00980	.00680	.00140	.11432	.00840
85,000	.17012	.05900	.00560	.00120	.17452	.06020
86,000	Specimen broke.					

GENERAL SUMMARY.

Specific gravity	7.8556
Ultimate strength per square inch	86,000 pounds.
Elastic limit	40,000 pounds.
Extension per inch at rupture	0.17012 inch.
Extension at elastic limit	0.00142 inch.
Hardness	16.230
Reduction in diameter at point of rupture	0.162 inch.
Original area of cross-section	0.344 square inch.
Area after rupture	0.1964 square inch.
Position of rupture	Central.
Character of surface	Crystals, fine and sharp

SPECIMEN E, No. II.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of section acting upon a solid cylinder 10 inches long (between shoulders) and 0″.662 in diameter, taken from a sample bar of fluid-compressed steel 6 inches square by 22 inches long, furnished by Sir Joseph Whitworth's Steel Works, Manchester, England.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	″	″	″	″	″	″
1,000	0.00004	0.00000	0.00004	0.00000	0.00000	0.00000
2,000	.00013	.00019	.00013	.00009	.00000	.00000
3,000	.00017	.00004	.00017	.00004	.00000	.00000
4,000	.00018	.00001	.00018	.00001	.00000	.00000
5,000	.00021	.00003	.00021	.00003	.00000	.00000
6,000	.00022	.00002	.00022	.00001	.00000	.00000
7,000	.00029	.00007	.00029	.00007	.00000	.00000
8,000	.00030	.00001	.00030	.00001	.00000	.00000
9,000	.00032	.00002	.00032	.00002	.00000	.00000
10,000	.00037	.00005	.00037	.00005	.00000	.00000
11,000	.00039	.00002	.00039	.00002	.00000	.00000
12,000	.00040	.00001	.00040	.00001	.00000	.00000
13,000	.00042	.00002	.00042	.00002	.00000	.00000
14,000	.00044	.00002	.00044	.00002	.00000	.00000
15,000	.00046	.00002	.00046	.00002	.00000	.00000
16,000	.00049	.00003	.00049	.00003	.00000	.00000
17,000	.00052	.00003	.00052	.00003	.00000	.00000
18,000	.00054	.00002	.00054	.00002	.00000	.00000
19,000	.00056	.00002	.00056	.00002	.00000	.00000
20,000	.00056	.00000	.00056	.00000	.00000	.00000
21,000	.00057	.00001	.00057	.00001	.00000	.00000
22,000	.00061	.00004	.00061	.00004	.00000	.00000
23,000	.00065	.00004	.00065	.00004	.00000	.00000
24,000	.00068	.00003	.00068	.00003	.00000	.00000
25,000	.00071	.00003	.00071	.00003	.00000	.00000
26,000	.00072	.00001	.00072	.00001	.00000	.00000
27,000	.00077	.00005	.00077	.00005	.00000	.00000
28,000	.00079	.00002	.00079	.00002	.00000	.00000
29,000	.00084	.00005	.00084	.00005	.00000	.00000
30,000	.00087	.00003	.00087	.00003	.00000	.00000
31,000	.00089	.00002	.00089	.00002	.00000	.00000
32,000	.00092	.00003	.00092	.00003	.00000	.00000
33,000	.00096	.00004	.00096	.00004	.00000	.00000
34,000	.00099	.00003	.00099	.00003	.00000	.00000
35,000	.00101	.00002	.00101	.00002	.00000	.00000
36,000	.00106	.00005	.00106	.00005	.00000	.00000
37,000	.00111	.00005	.00111	.00005	.00000	.00000
38,000	.00162	.00011	.00099	.00012	.00023	.00000
39,000	.00192	.00070	.00120	.00021	.00072	.00049
40,000	.00504	.00312	.00156	.00026	.00348	.00276
41,000	.00554	.00050	.00156	.00001	.00397	.00049
42,000	.00615	.00061	.00158	.00001	.00457	.00060
43,000	.00662	.00057	.00163	.00005	.00499	.00042
44,000	.00767	.00105	.00173	.00010	.00594	.00095
45,000	.00337	.00070	.00190	.00017	.00647	.00053
50,000	.01257	.00420	.00197	.00007	.01060	.00413
55,000	.01782	.00525	.00237	.00040	.01545	.00485
60,000	.02400	.00618	.00269	.00032	.02131	.00586
65,000	.03052	.00652	.00272	.00003	.02780	.00649
70,000	.03847	.00795	.00335	.00037	.03512	.00732
75,000	.05326	.01479	.00362	.00027	.04964	.01432
80,000	.07668	.02342	.00411	.00049	.07251	.02287
85,000	.13980	.06312	.00418	.00007	.13562	.06311
86,000	.17992	.04012	.00145	.00273	.17847	.04285

GENERAL SUMMARY.

Specific gravity 7.8528
Ultimate strength per square inch .... 86,000 pounds.
Elastic limit .... 38,000 pounds.
Extension per inch at rupture .... 0.17992 inch.
Extension at elastic limit .... 0.00162 inch.

Hardness	16.230	
Reduction in diameter at point of rupture	0.163	inch.
Original area of cross-section	0.342	square inch.
Area after rupture	0.194	square inch.
Position of rupture	Central.	
Character of surface	Fine silky.	

SPECIMEN No. 1.

Table showing the compression, restoration, and permanent set caused by the undermentioned weights per square inch of section acting upon a solid cylinder 10 *inches long and* 1''.125 *in diameter, taken from a sample bar of fluid-compressed steel* 6 *inches square by* 22 *inches long, furnished by Sir Joseph Whitworth's Steel Works, Manchester, England.*

Weight per square inch of section.	Compression per inch in length.	Successive compression per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	''	''	''	''	''	
1.000	0.00011	....	0.00011	....	0.00000	....
2.000	.00023	0.00012	.00023	0.00012	.00000	....
3.000	.00028	.00005	.00028	.00005	.00000	....
4.000	.00040	.00012	.00040	.00012	.00000	....
5.000	.00046	.00006	.00046	.00006	.00000	....
6.000	.00049	.00003	.00049	.00003	.00000	....
7.000	.00052	.00003	.00052	.00003	.00000	....
8.000	.00059	.00007	.00059	.00007	.00000	....
9.000	.00060	.00003	.00062	.00003	.00000	....
10.000	.00066	.00004	.00066	.00004	.00000	....
11.000	.00071	.00005	.00071	.00005	.00000	....
12.000	.00074	.00003	.00074	.00003	.00000	....
13.000	.00078	.00004	.00078	.00004	.00000	....
14.000	.00081	.00003	.00081	.00003	.00000	....
15.000	.00085	.00004	.00085	.00004	.00000	....
16.000	.00088	.00003	.00088	.00005	.00000	....
17.000	.00092	.00004	.00092	.00004	.00000	....
18.000	.00097	.00005	.00097	.00005	.00000	....
19.000	.00101	.00004	.00101	.00004	.00000	....
20.000	.00106	.00005	.00106	.00005	.00000	....
21.000	.00109	.00003	.00109	.00003	.00000	....
22.000	.00117	.00008	.00117	.00008	.00000	....
23.000	.00126	.00009	.00126	.00009	.00000	....
24.000	.00128	.00002	.00128	.00002	.00000	....
25.000	.00130	.00002	.00130	.00002	.00000	....
26.000	.00135	.00005	.00155	.00005	.00000	....
27.000	.00140	.00005	.00140	.00005	.00000	....
28.000	.00143	.00003	.00143	.00003	.00000	....
29.000	.00148	.00005	.00148	.00005	.00000	....
30.000	.00155	.00007	.00155	.00007	.00000	....
36.000	.00182	.00027	.00181	.00006	.00001	.00001
40.000	.00207	.00027	.00197	.00016	.00010	.00009
44.000	.00683	.000476	.00216	.00019	.00467	.00457

GENERAL SUMMARY.

Elastic limit	36,000	pounds.
Compression per inch at 44,000 pounds	0.00683	inch.
Compression at elastic limit	0.00182	inch.
Increase in diameter at 44,000 pounds	0.003	inch.
Original area of cross-section	0.9940	square inch.
Area after 44,000 pounds	0.9993	square inch

SPECIMEN No. 2.

Table showing the compression, restoration, and permanent set caused by the under-mentioned weights per square inch of section, acting upon a solid cylinder 10 inches long and 1″.125 in diameter, taken from a sample bar of fluid compressed steel 6 inches square by 22 inches long, furnished by Sir Joseph Whitworth's Steel Works, Manchester, England.

Weight per square inch of section.	Compression per inch in length.	Successive compression per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	″	″	″	″	″	″
1, 000	0. 00002	0. 00000	0. 00002	0. 00000	0. 00000	0. 00000
2, 000	. 00012	. 00010	. 00012	. 00010	. 00000	. 00000
3, 000	. 00020	. 00008	. 00020	. 00008	. 00000	. 00000
4, 000	. 00030	. 00010	. 00030	. 00010	. 00000	. 00000
5, 000	. 00038	. 00008	. 00038	. 00008	. 00000	. 00000
6, 000	. 00045	. 00007	. 00045	. 00007	. 00000	. 00000
7, 000	. 00052	. 00007	. 00052	. 00007	. 00000	. 00000
8, 000	. 00057	. 00005	. 00057	. 00005	. 00000	. 00000
9, 000	. 00062	. 00005	. 00062	. 00005	. 00000	. 00000
10, 000	. 00069	. 00007	. 00069	. 00007	. 00000	. 00000
11, 000	. 00073	. 00006	. 00073	. 00004	. 00000	. 00000
12, 000	. 00078	. 00005	. 00078	. 00005	. 00000	. 00000
13, 000	. 00083	. 00005	. 00083	. 00005	. 00000	. 00000
14, 000	. 00087	. 00004	. 00087	. 00004	. 00000	. 00000
15, 000	. 00095	. 00008	. 00097	. 00008	. 00000	. 00000
16, 000	. 00099	. 00004	. 00099	. 00006	. 00000	. 00000
17, 000	. 00101	. 00002	. 00101	. 00002	. 00000	. 00000
18, 000	. 00102	. 00001	. 00102	. 00001	. 00000	. 00000
19, 000	. 00107	. 00005	. 00107	. 00005	. 00000	. 00000
20, 000	. 00112	. 00005	. 00112	. 00005	. 00000	. 00000
21, 000	. 00114	. 00002	. 00114	. 00002	. 00000	. 00000
22, 000	. 00118	. 00004	. 00118	. 00006	. 00000	. 00000
23, 000	. 00124	. 00006	. 00124	. 00006	. 00000	. 00000
24, 000	. 00127	. 00003	. 00127	. 00003	. 00000	. 00000
25, 000	. 00131	. 00004	. 00131	. 00004	. 00000	. 00000
26, 000	. 00135	. 00004	. 00133	. 00002	. 00002	. 00002
27, 000	. 00140	. 00005	. 00138	. 00005	. 00002	. 00000
28, 000	. 00145	. 00005	. 00142	. 00004	. 00003	. 00001
29, 000	. 00149	. 00004	. 00144	. 00002	. 00005	. 00002
30, 000	. 00154	. 00005	. 00148	. 00004	. 00006	. 00001
31, 000	. 00161	. 00007	. 00154	. 00006	. 00007	. 00001
32, 000	. 00172	. 00011	. 00162	. 00008	. 00010	. 00003
33, 000	. 00178	. 00006	. 00166	. 00004	. 00012	. 00002
34, 000	. 00184	. 00006	. 00171	. 00005	. 00013	. 00001
35, 000	. 00191	. 00007	. 00176	. 00005	. 00015	. 00002
36, 000	. 00197	. 00006	. 00179	. 00003	. 00018	. 00003
37, 000	. 00202	. 00005	. 00180	. 00001	. 00022	. 00004
38, 000	. 00210	. 00008	. 00176	—. 00004	. 00034	. 00012
39, 000	. 00220	. 00010	. 00182	+. 00006	. 00038	. 00004
40, 000	. 00227	. 00007	. 00181	—. 00001	. 00046	. 00008
41, 000	0. 00266	0. 00039	0. 00180	—0. 00001	0. 00086	0. 00040

GENERAL SUMMARY.

Elastic limit..pounds.. 25,000
Compression per inch at 41,000 pounds ....inch.. 0.00266
Compression at elastic limit ....do... 0.00131
Increase in diameter at 41,000 pounds ....do... 0.0025
Original area of cross section ....square inch.. 0.9[illegible]
Area after 41,000 pounds ....do... 0.9933

RECORD OF TESTS OF WHITWORTH'S FLUID COMPRESSED STEEL EMPLOYED IN JACKET OF TUBE FOR 8-INCH BREECH-LOADING RIFLE.

APPENDIX II.

8-INCH BREECH-LOADING RIFLE.

SPECIMEN I.

Table showing the extension, restoration, and permanent set caused by the under-mentioned weights per square inch of section acting upon a solid cylinder of fluid compressed steel, 6 inches long (between shoulders) and 0''.653 in diameter, taken from jacket of tube for 8-inch breech-loading rifle, furnished by Sir Joseph Whitworth's Steel Works, Manchester, England.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	"	"	"	"	"	"
1.000	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000
2,000	.00003	.00002	.00003	.00002	.00000	.00000
3,000	.00006	.00003	.00006	.00003	.00000	.00000
4.000	.00010	.00004	.00010	.00004	.00000	.00000
5.000	.00016	.00006	.00016	.00006	.00000	.00000
6.000	.00020	.00004	.00020	.00004	.00000	.00000
7.000	.00021	.00001	.00021	.00001	.00000	.00000
8.000	.00026	.00005	.00026	.00005	.00000	.00000
9.000	.00030	.00004	.00030	.00004	.00000	.00000
10,000	.00033	.00003	.00033	.00003	.00000	.00000
11.000	.00040	.00007	.00040	.00007	.00000	.00000
12.000	.00040	.00000	.00040	.00000	.00000	.00000
13.000	.00043	.00003	.00043	.00003	.00000	.00000
14.000	.00050	.00007	.00050	.00007	.00000	.00000
15.000	.00043	.00007	.00043	.00007	.00000	.00000
16.000	.00051	.00008	.00051	.00008	.00000	.00000
17.000	.00053	.00002	.00053	.00002	.00000	.00000
18.000	.00055	.00002	.00055	.00002	.00000	.00000
19.000	.00056	.00001	.00056	.00001	.00000	.00000
20.000	.00061	.00005	.00061	.00005	.00000	.00000
21.000	.00066	.00005	.00066	.00005	.00000	.00000
22,000	.00070	.00004	.00070	.00004	.00000	.00000
23,000	.00071	.00001	.00071	.00001	.00000	.00000
24.000	.00075	.00004	.00075	.00004	.00000	.00000
25.000	.00081	.00006	.00081	.00006	.00000	.00000
26.000	.00086	.00005	.00086	.00005	.00000	.00000
27,000	.00088	.00002	.00088	.00002	.00000	.00000
28,000	.00093	.00005	.00093	.00005	.00000	.00000
29,000	.00101	.00008	.00101	.00008	.00000	.00000
30,000	.00105	.00004	.00105	.00004	.00000	.00000
31.000	.00118	.00013	.00118	.00013	.00000	.00000
32,000	.00123	.00005	.00123	.00005	.00000	.00000
33,000	.00140	.00017	.00140	.00017	.00000	.00000
34,000	.00166	.00026	.00133	—.00007	.00033	.00033
35,000	.00183	.00017	.00116	—.00017	.00065	.00032
36,000	.00233	.00050	.00133	.00017	.00100	.00035
37,000	.00266	.00033	.00150	.00017	.00116	.00016
38,000	.00283	.00017	.00150	.00000	.00133	.00017
39,000	.00316	.00033	.00166	.00016	.00150	.00017
40,000	.00333	.00017	.00166	.00000	.00167	.00017
41,000	.00383	.00050	.00185	.00019	.00198	.00031
42.000	.00400	.00017	.00166	—.00019	.00234	.00036
43,000	.00433	.00033	.00185	.00019	.00248	.00014
44.000	.00466	.00033	.00185	.00000	.00281	.00033
45.000	.00516	.00050	.00185	.00000	.00331	.00050
46.000	.00583	.00067	.00200	.00015	.00383	.00052
47.000	.00633	.00050	.00200	.00000	.00433	.00050
48,000	.00716	.00083	.00233	.00033	.00483	.00050
49.000	.00783	.00067	.00233	.00000	.00550	.00067
50,000	.00833	.00050	.00233	.00000	.00600	.00050
51.000	.00850	.00017	.00166	.00067	.00684	.00084
52.000	.00983	.00133	.00233	.00067	.00750	.00066

Specimen I—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	"	"	"	"	"	"
53, 000	0. 01066	0. 00183	0. 00233	0. 00000	0. 00833	0. 00083
54, 000	. 01150	. 00084	. 00250	. 00017	. 00900	. 00067
55, 000	. 01250	. 00100	. 00266	. 00016	. 00984	. 00084
56, 000	. 01316	. 00066	. 00250	— . 00016	. 01066	. 00082
57, 000	. 01416	. 00100	. 00266	. 00016	. 01150	. 00084
58, 000	. 01566	. 00150	. 00366	. 00100	. 01200	. 00050
59, 000	. 01650	. 00084	. 00283	— . 00083	. 01367	. 00167
60, 000	. 01750	. 00100	. 00300	. 00017	. 01450	. 00083
61, 000	. 01850	. 00100	. 00283	— . 00017	. 01567	. 00117
62, 000	. 01983	. 00133	. 00316	. 00033	. 01667	. 00100
63, 000	. 02100	. 00117	. 00316	. 00000	. 01784	. 00117
64, 000	. 02250	. 00150	. 00150	— . 00166	. 02100	. 00316
65, 000	. 02400	. 00150	. 00333	. 00183	. 02067	. 00333
66, 000	. 02566	. 00166	. 00333	. 00000	. 02233	. 00166
67, 000	. 02733	. 00167	. 00333	. 00000	. 02400	. 00167
68, 000	. 02916	. 00183	. 00450	. 00117	. 02466	. 00066
69, 000	. 03066	. 00150	. 00466	. 00016	. 02600	. 00134
70, 000	. 03266	. 00167	. 00383	— . 00083	. 02850	. 00250
71, 000	. 03366	. 00133	. 00366	— . 00017	. 03000	. 00150
72, 000	. 03566	. 00200	. 00383	. 00017	. 03183	. 00183
73, 000	. 03783	. 00217	. 00400	. 00017	. 03383	. 00200
74, 000	. 03966	. 00183	. 00400	. 00000	. 03566	. 00183
75, 000	. 04316	. 00350	. 00483	. 00083	. 03933	. 00367
76, 000	. 04583	. 00267	. 00433	— . 00050	. 04150	. 00217
77, 000	. 04900	. 00317	. 00416	— . 00017	. 04484	. 00334
78, 000	. 05216	. 00316	. 00450	. 00034	. 04766	. 00282
79, 000	. 05566	. 00350	. 00366	— . 00084	. 05200	. 00434
80, 000	. 06033	. 00467	. 00483	. 00117	. 05550	. 00350
81, 000	. 06500	. 00467	. 00466	— . 00017	. 06034	. 00484
82, 000	. 06983	. 00483	. 00500	. 00034	. 06483	. 00449
83, 000	. 07566	. 00583	. 00500	. 00000	. 07066	. 00583
84, 000	. 07783	. 00217	. 00116	— . 00384	. 07567	. 00500
85, 000	. 09116	. 00333	. 00516	. 00400	. 08600	. 01033
86, 000	. 10050	. 00934	. 00400	— . 00116	. 09650	. 01050
87, 000	. 12116	. 02066	. 00533	. 00133	. 11583	. 01933
88, 000	. 14650	. 02534	0. 00583	0. 00050	0. 14067	0. 02484
89, 000	0. 19316	0. 04666	(*)	(*)	(*)	(*)

* Specimen broke.

GENERAL SUMMARY.

Specific gravity	7. 8491
Ultimate resistance to extension......pounds..	89, 000
Elastic limit......pounds..	33, 000
Extension per inch at rupture......inch..	0. 19316
Extension at elastic limit......inch..	0. 00140
Hardness	16. 258
Reduction in diameter at point of rupture......inch..	0. 178
Original area of cross section......square inch..	0. 332
Area after rupture......square inch..	0. 1772
Position of rupture	Near middle.
Character of surface	Dull, gray, fibrous.

SPECIMEN II.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of section acting upon a solid cylinder of fluid-compressed steel, 6 inches long (between shoulders) and 0″.653 in diameter, taken from jacket of tube for 8-inch breech-loading rifle, furnished by Sir Joseph Whitworth's Steel Works, Manchester, England.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	″	″	″	″	″	″
1,000	0.00005	0.00005	0.00005	0.00005	0.00000	0.00000
2,000	.00010	.00005	.00010	.00005	.00000	.00000
3,000	.00013	.00003	.00013	.00003	.00000	.00000
4,000	.00016	.00003	.00016	.00003	.00000	.00000
5,000	.00018	.00002	.00018	.00002	.00000	.00000
6,000	.00022	.00004	.00022	.00004	.00000	.00000
7,000	.00035	.00013	.00035	.00013	.00000	.00000
8,000	.00039	.00004	.00039	.00004	.00000	.00000
9,000	.00040	.00001	.00040	.00001	.00000	.00000
10,000	.00049	.00009	.00049	.00009	.00000	.00000
11,000	.00052	.00003	.00052	.00003	.00000	.00000
12,000	.00055	.00003	.00055	.00003	.00000	.00000
13,000	.00057	.00002	.00057	.00002	.00000	.00000
14,000	.00059	.00002	.00059	.00002	.00000	.00000
15,000	.00065	.00006	.00065	.00006	.00000	.00000
16,000	.00072	.00007	.00072	.00007	.00000	.00000
17,000	.00074	.00002	.00074	.00002	.00000	.00000
18,000	.00077	.00003	.00077	.00003	.00000	.00000
19,000	.00082	.00005	.00082	.00005	.00000	.00000
20,000	.00087	.00005	.00087	.00005	.00000	.00000
21,000	.00092	.00005	.00092	.00005	.00000	.00000
22,000	.00102	.00010	.00102	.00010	.00000	.00000
23,000	.00107	.00005	.00107	.00005	.00000	.00000
24,000	.00113	.00006	.00113	.00006	.00000	.00000
25,000	.00117	.00004	.00117	.00004	.00000	.00000
26,000	.00122	.00005	.00122	.00122	.00000	.00000
27,000	.00139	.00017	.00139	.00139	.00000	.00000
28,000	.00147	.00008	.00147	.00147	.00000	.00000
29,000	.00160	.00013	.00160	.00160	.00000	.00000
30,000	.00175	.00015	.00175	.00175	.00000	.00000
31,000	.00216	.00041	.00216	.00216	.00000	.00000
32,000	.00267	.00051	.00150	.00150	.00117	.00000
33,000	.00300	.00033	.00117	— .00033	.00183	.00066
34,000	.00400	.00100	.00133	.00016	.00267	.00084
35,000	.00483	.00083	.00133	.00000	.00350	.00083
36,000	.00550	.00067	.00133	.00000	.00417	.00067
37,000	.00633	.00083	.00117	— .00016	.00516	.00099
38,000	.00733	.00100	.00138	.00033	.00513	.00067
39,000	.00800	.00067	.00167	.00017	.00633	.00050
40,000	.00867	.00067	.00150	— .00017	.00717	.00084
41,000	.00983	.00116	.00150	.00000	.00833	.00116
42,000	.01067	.00084	.00133	— .00017	.00934	.00101
43,000	.01133	.00066	.00167	.00034	.00966	.00032
44,000	.01217	.00084	.00150	— .00017	.01067	.00101
45,000	.01400	.00183	.00167	.00017	.01233	.00166
46,000	.01483	.00083	.00167	.00000	.01316	.00083
47,000	.01600	.00117	.00200	.00033	.01400	.00084
48,000	.01717	.00117	.00167	— .00033	.01550	.00150
49,000	.01817	.00117	.00183	.00016	.01634	.00084
50,000	.01967	.00150	.00167	— .00016	.01800	.00166
51,000	.02050	.00083	.00217	.00050	.01833	.00033
52,000	.02217	.00167	.00217	.00000	.02000	.00167
53,000	.02467	.00250	.00217	.00000	.02250	.00250
54,000	.02583	.00116	.00217	.00000	.02316	.00116
55,000	.02716	.00133	.00233	.00016	.02483	.00117
60,000	.03633	.00917	.00250	.00017	.03383	.00900
65,000	.04833	.01200	.00317	.00067	.04516	.01133
70,000	.06563	.01730	.00350	.00033	.06213	.01697
75,000	.10300	.03737	.00333	— .00017	.09967	.03754
76,000	.12100	.01800	.00467	.00134	.11633	.01666
77,000	.14733	.02633	.00467	.00000	.14266	.02633
78,000	0.21717	0.06934	0.01833	0.01366	0.19884	0.05618

GENERAL SUMMARY.

Specific gravity		7.8561
Ultimate resistance to extension	pounds	78,000
Elastic limit	do	32,000
Extension per inch at rupture	inch	0.21717
Extension at elastic limit	do	0.00267
Hardness		16.250
Reduction in diameter at point of rupture	inch	0.147
Original area of cross-section	square inch	0.3349
Area after rupture	do	0.2011
Position of rupture		Near middle.
Character of surface		Part granular and part fibrous.

Appendix III.

Description of the instruments employed in the measurements of the expansion and the corresponding temperature of the cast-iron casing of the 8-inch breech-loading rifle, when heated up for the reception of its tube.

The method *by shrinkage* having been adopted for the insertion of the tube of the 8-inch breech-loading rifle, it at once became important to provide some reliable means for measuring, from time to time, the expansion of the cast-iron casing while undergoing heating. It was deemed most desirable, also, in connection with these measurements, to determine accurately the corresponding temperatures, in order to acquire trustworthy data, which might serve for reference in future operations of this nature. The instruments prepared for the above purposes were as follows:

1. For the measurement of the expansion.

In this operation, since the instrument would require to be inserted within the bore of the heated casing, it was deemed necessary to employ a measuring tool of such poor conducting material as would undergo itself as little change from the heat as possible. Accordingly, a number of wooden measuring-rods (Plate II), with steel points screwed into the ends, were constructed. The lengths of these rods were then adjusted by a vernier rule, reading to 0″.001, so as to form a series, gradually increasing by 0″.005, from 22″.00 to 22″.09, or to a little beyond the required expansion. The length of each measuring-rod was stamped upon it, and a stiff wire attached to it at the middle, by which to handle it in taking a measurement. By means of these rods, using a longer and longer one till one was found that would just enter the casing, the measurements of the interior diameter of the heated casing were rapidly and, it is thought, quite accurately made. The lengths of the measuring-rods, as verified by the vernier rule, immediately after being withdrawn, showed no sensible change.

This mode of measurement was devised by the South Boston Iron Company.

2. For the measurement of the temperature.

For the determination of the temperature it was decided to employ a pyrometer of the form known as the hydro-pyrometer; in which the temperature is ascertained by exposing to the action of the heat which is to be measured a definite weight of some metal, as platinum, steel, copper, &c., and then quenching the same in a known weight of water, and noting the rise in temperature of the latter. From this data, and the specific heat of the metal employed, the initial temperature of the metal, which is the temperature required, can be readily obtained. Thus, if a

piece of platinum weighing 1,000 grains should, when immersed in 2,000 grains of water at a temperature of 60° Fahrenheit, raise the temperature of the latter to 90°, then 90°−60°=30°, multiplied by 2 because the weight of the water is twice that of the platinum, gives 60°, the temperature to which a weight of water equal to the platinum would have been raised. To obtain from this the initial temperature of the platinum, in Fahrenheit degrees, we multiply by 31¼, the specific heat of water as compared with platinum, that of the latter being 1, and to the result add the temperature of the water. Therefore $(60 \times 30\frac{1}{4}) + 90 = 1965$ is the temperature required.* The principle may otherwise be stated as follows:† A body of known weight W is raised to a final temperature T, and then plunged into a quantity of water of weight W′ and temperature t, which is contained in a copper vessel called a "calorimeter." As T is supposed to exceed t, the water gains in temperature by the immersion of the body and finally attains a maximum temperature θ, which is noted. In the change from t to θ, the water has gained a quantity of heat equal to $W'(\theta - t)$, and the body immersed has lost a quantity equal to $Wx(T-\theta)$; x being the specific heat of the body, that of water being equal to 1.

Equating these two quantities, we have

$$W'(\theta - t = Wx(T-\theta)$$

Solving in reference to T, we obtain

$$T = \frac{W'(\theta-t)}{Wx} + \theta$$

This method of pyrometric measurement was first adopted by Clement-Desormes & Schwarz, for the measurement of the heat of furnaces; it was afterward employed by Regnault in the determination of the specific heats of various substances, liquid and solid, and by Dr. Siemens in some delicate experiments upon the varying electrical conductivity of telegraph wire under different degrees of temperature. The form of the instrument has varied somewhat with the specific end in view; the one herein described is essentially that devised by Captain Byström, of the Swedish artillery.

DESCRIPTION OF THE INSTRUMENT.

Plate IV.—The instrument consists of a copper vessel, C the calorimeter, inclosed in a wooden box A, but separated from it by an air space E an outlet pipe, closed with a cork, is provided at the bottom of the vessel for withdrawing the water; D is the metal ball, in this instance of copper;‡ B is the "mixer," consisting of a cage of brass wires, fastened into a wooden ring; the latter serves as a handle for turning the mixer, and also as a socket for the funnel used in filling with water, or dropping in the heated metal ball. The mixer is detachable, and by means of it the ball can be withdrawn from the calorimeter. During an experiment the funnel-hole is closed by a rubber ball, to prevent the escape of heat. T represents the thermometer, which enters through a rubber packing, a short open tube in the top of the calorimeter. The thermometer is provided with a sliding index, which will be described more fully subsequently. A mahogany casing G is placed over the in-

*Mitchell's Assaying.

†Deschanel's Natural Philosophy.

‡Platinum is perhaps the metal best suited for this purpose, as its specific heat remains constant up to very high temperatures; it is objectionable, however, on the ground of expense. Steel would have been preferable to copper, but time did not permit the procuring of a suitable piece and ascertaining its specific heat.

strument to give an exterior finish, and also to afford additional protection; it may be readily removed like a cover. The inner box is of pine wood, coated with shellac.

The amount of water employed is 65 cubic inches, at the temperature of 62° F., or 34.192 ounces. The water may be either weighed or measured; the latter is a more convenient method, when the temperature of the water does not vary much from 62°, and was adopted in the experiments had with this instrument. The measurement was made by means of a graduated glass, liquid measure (Plate 5). The weight of the copper ball is 5.012 ounces. In order that the temperature of the copper ball should truly represent that of the gun-casing, it was deemed best to suspend it in the bore of the casing. For this purpose a small cast-iron box* was provided, capable of containing the ball, and having a bottom movable about a pivot at one corner. By means of a projecting arm, E, the bottom could be turned round so as to allow the ball to fall out into the calorimeter. A piece of gas-pipe was screwed to the top of the box, having attached to it by a set-screw an adjustable cross-arm. By means of this apparatus the copper ball could be suspended at any height in the bore of the casing, its transfer to the calorimeter be rapidly and easily made, while the heat lost during that operation would necessarily take place from the outside box, rather than from the copper ball within. The details of the heating-box, and the method of its employment, are shown on Plate 5. This plate also gives a view of the gun-pit and the method of heating it; D being the fire-pit; FF the inlet and O the outlet air-flues; CC are flask-sections; K a muzzle-rest; EE, barees for the support of the gun.

DETERMINATION OF THE WATER EQUIVALENT OF THE PYROMETER.

The equation

$$T = \frac{W' \ (\theta - t)}{Wx} + \theta$$

assumes that the only exchange of heat is between the water and the heated body, which is not actually the case.

The heat of the body is not given up exclusively to the water in the calorimeter, but partly to the calorimeter itself, to the thermometer, the mixer, and such other instruments as may be employed in the experiments and come in contact directly or indirectly with the heated body.†

The equation for the most general case can easily be written down, since it is only necessary to express that the quantity of heat given up by the heated body is equal to that gained by the water, the calorimeter, thermometer, mixer, &c.

Let W denote the weight of the body; T its initial temperature; x its specific heat; W′ the weight of the water in the calorimeter; w' the weight of the calorimeter; x' its specific heat; w'' the weight of the mixer, and x'' its specific heat; w''' the weight of the thermometer-tube immersed in the water; x''' its specific heat, and w^{iv} the weight of the mercury in the thermometer-tube, and x^{iv} its specific heat.

Then

$$Wx \ (T - \theta) = W' + w'x' + w''x'' + w'''x''' + w^{iv}x^{iv}) \ (\theta - t)$$

and

$$T = \frac{(W' + w'x' + w''x'' + w'''x''' + w^{iv}x^{iv}) \ (\theta - t)}{Wx} + \theta$$

* The form of this heating-box was suggested by Mr. Pearse, of the South Boston Iron Company, and is an improvement upon the one designed at this office.

† Deschanel's Natural Philosophy.

In the above expression the coefficient of $(\theta - t)$ is called the *water equivalent of the calorimeter*, and evidently represents a mass of water such that, supposing it to receive exclusively all the heat given up in the experiment, a thermometer placed in it would indicate the variation of temperature actually observed.

To determine this value for the particular case under consideration, take the following schedule:

Parts.	Material.	Weight, ozs.	Symbol.	Specific heat, at 57½° F.	Symbol.	Thermal capacity.	Numerical value.	
Ball.	Copper.	5.012.	W.	.1013.	x.	Wx.	.50772.	
Water		34.192	W′	1.	......	W′		34.192
Calorimeter	Copper	11.23	w'	.1013	x'	$w'x'$		1.1376
Mixer	Brass	1.51	w''	.1002	x''	$w''x''$		.1513
Thermometer-tube	Glass	.25	w'''	.199	x'''	$w'''x'''$		.0498
Mercury in thermometer-tube		.30	w^{iv}	.035	x^{iv}	$w^{iv}x^{iv}$		.0105
$W' + w'x' + w''x'' + w'''x''' + w^{iv}x^{iv} =$							.50772	35.5412

From which we determine—

$$\frac{W' + w'x' + w''x'' + w'''x''' \; w^{iv}x^{iv}}{WX} = \frac{35.5412}{.50772} = 70.$$

for the water equivalent of the pyrometer, or the value of each degree in the difference between the temperature of the water before and after the immersion of the heated copper. The expression for the temperature thus becomes $T = 70\ (\theta - t) + \theta$.

The thermometer—Plate IV—ranges from 50° to 105° Fahrenheit, and is graduated upon the tube itself into degrees and fifths of a degree. Upon one side is an ivory slide with the same graduation as that on the glass tube; the unit of this scale, however, is 70°. Tenths of a degree can easily be read on the glass tube by the naked eye; and with the magnifying glass (Plate V) a still finer division may be made.

In using the instrument it is first filled with the requisite weight of water, and the slide moved until its zero coincides with the top of the mercurial column in the thermometer-tube. After immersing the heated copper ball and closing the aperture with the stopper, the temperature is equalized by stirring with the mixer, or by shaking gently the instrument. The height of the mercury is then read off from the slide, and to it is added the corresponding temperature of the water; the result is the temperature required.*

In addition to those corrections introduced in the determination of the water equivalent, there are yet others which it is usual to take into account where a rigorous result is desired. Thus the pyrometer loses a certain amount of heat by radiation and also by conduction through the supports on which it rests. With regard to the former, the necessary correction may either be allowed for, as by the "method of compensa-

* The unit of the scale on the slide is so large, 70°, that in practice it was found much easier to neglect this scale, and, instead of it, multiply the difference between the readings on the tube before and after an experiment by 70°.

tion," or it may be determined by calculation, and then directly applied to the result. The construction of the pyrometer, however, is such as to render this source of error so small, that it may be practically neglected. The same observation applies to loss of heat by conduction through the supports, which are of small dimensions and of a bad conducting material. For a difference between the temperature of the water and the air of 24° and an actual temperature of the former of over 100°, the loss of heat from the above sources was only one-tenth of a degree ($0^\circ.1$) in one minute and a half; a longer interval than is ordinarily required for an experiment with the instrument.

This pyrometer was constructed by Mr. James Green, of New York city in consultation with this office. Previously to its being employed at the South Boston foundery, in connection with the insertion of the tube of the 8-inch breech-loading rifle, it was carefully tested at this office by comparison with a high-range mercurial thermometer; the bulb of the thermometer and the copper ball being heated side by side in an oil-bath. The accordance between the results furnished by the two instruments was striking.* The employment of the pyrometer at the foundery was attended with success, and the results obtained were highly satisfactory. It is only to be regretted that circumstances did not permit of a wider range in the experiments.

It is respectfully suggested, therefore, that a series of experiments for the determination of data on the expansion of cast iron under gradually increasing temperatures, say from 212° to $1,000^\circ$ or more, be undertaken, whenever a fitting opportunity shall offer; employing for the purpose the instruments above described, and the cast-iron cylinder constructed or experimental purposes, now on hand in the department.

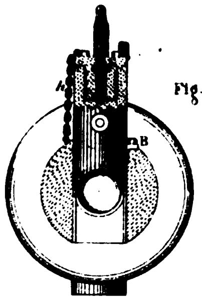
*

	In water-bath.	In oil-bath.		
	Degrees.	Degrees.		
Thermometer	212.	390.	430	500.
Hydro-pyrometer	211.7	389.9	432	499.92

8 INCH B.L. RIFLE.

Converted from a 10 inch Rodman smooth bore, by lining with a steel jacketed, coiled wrought-iron tube inserted from the breech jacket of tube being prolonged to the rear; and adapted for reception of the round wedge fermeture

Fig. 3.



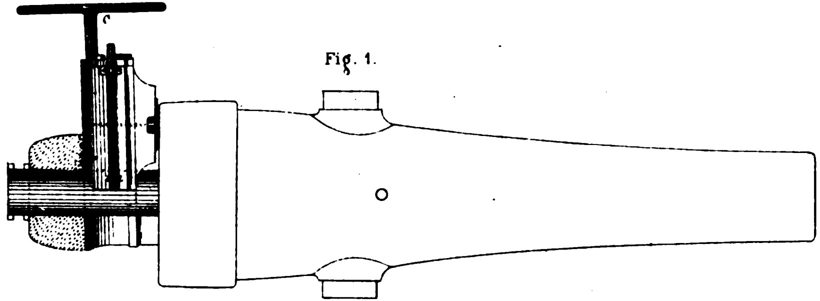
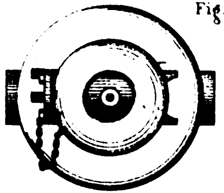


Fig. 1.

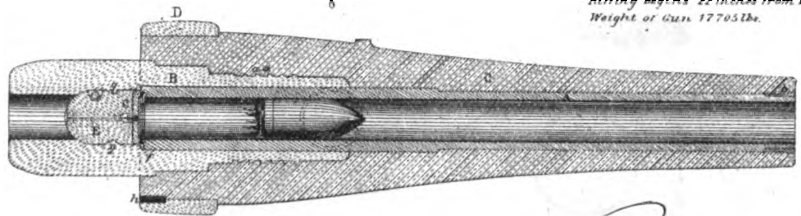
Fig. 4.



RIFLING

Twist uniform one turn in 40 feet
15 Grooves and Lands each 0.83776 in wide
Grooves 0.075 in deep
" Filleted with a rad. of 0.02 in
Lands beveled " " " 0.01 in
Rifling begins 22 inches from bottom of bore.
Weight of Gun 17705 lbs.

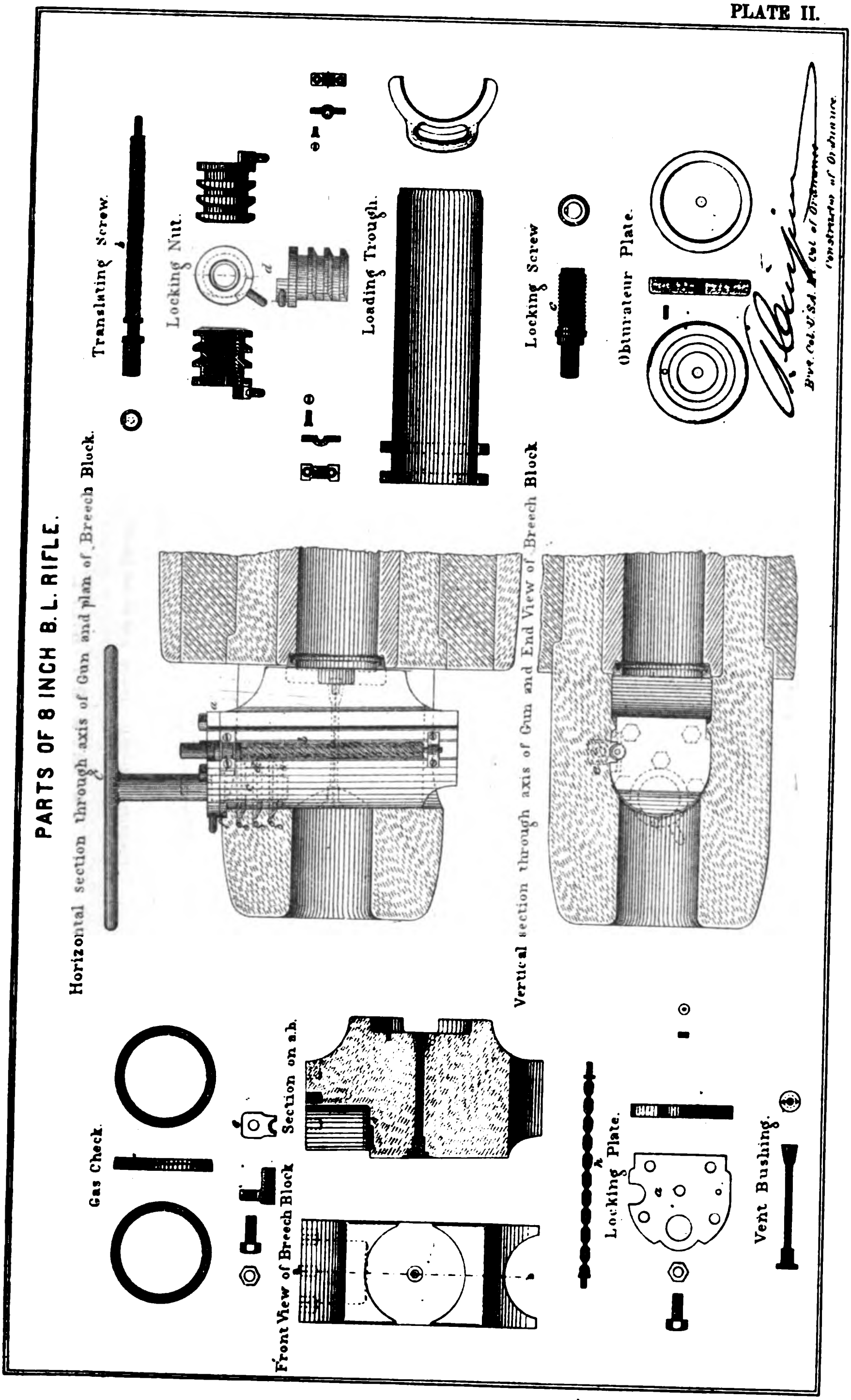
Fig. 2.



Scale.

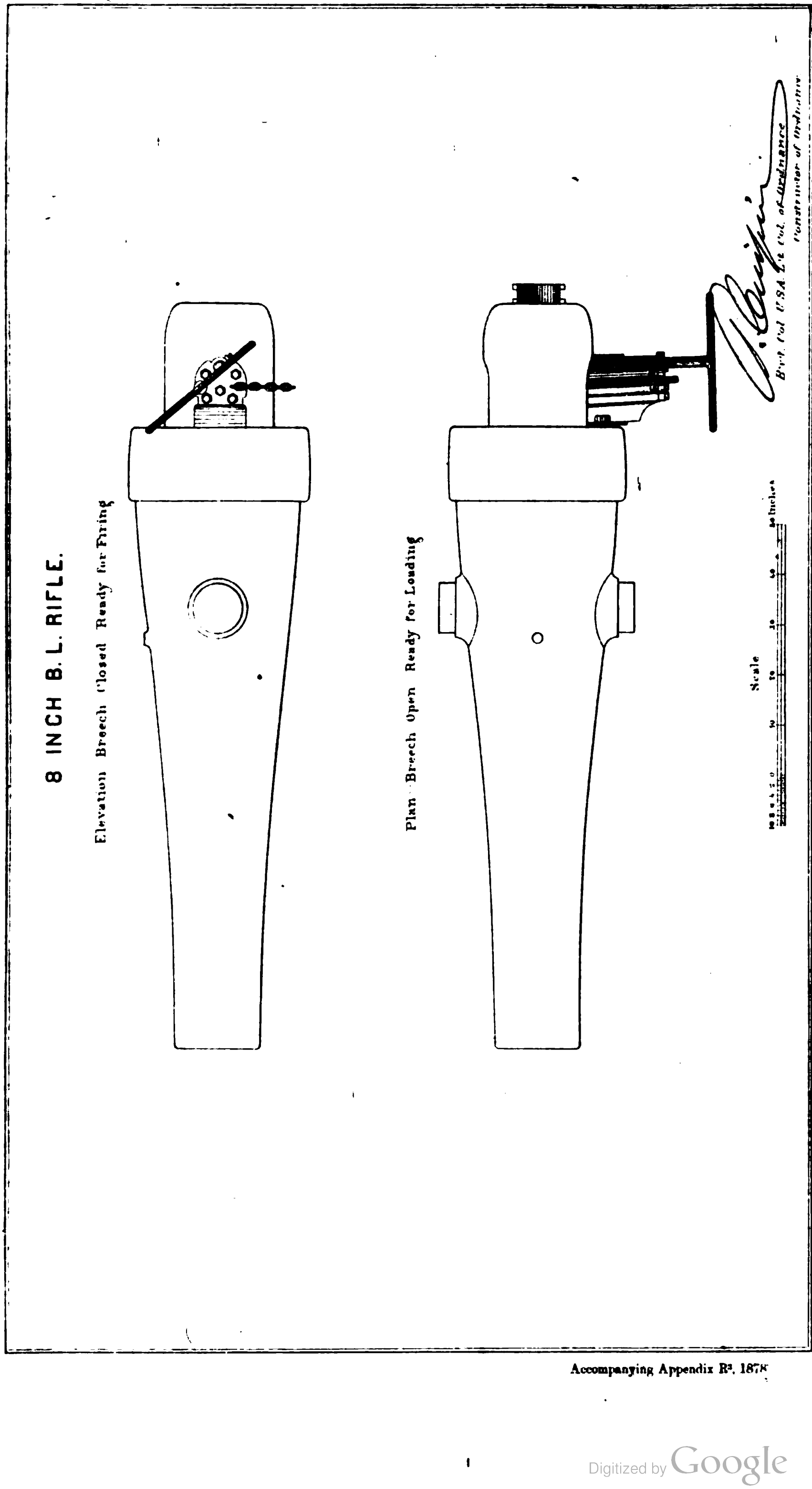
S. Crispin
Bvt. Col. U.S.A. Lt. Col. of Ordnance
Constructor of Ordnance.

PLATE II.

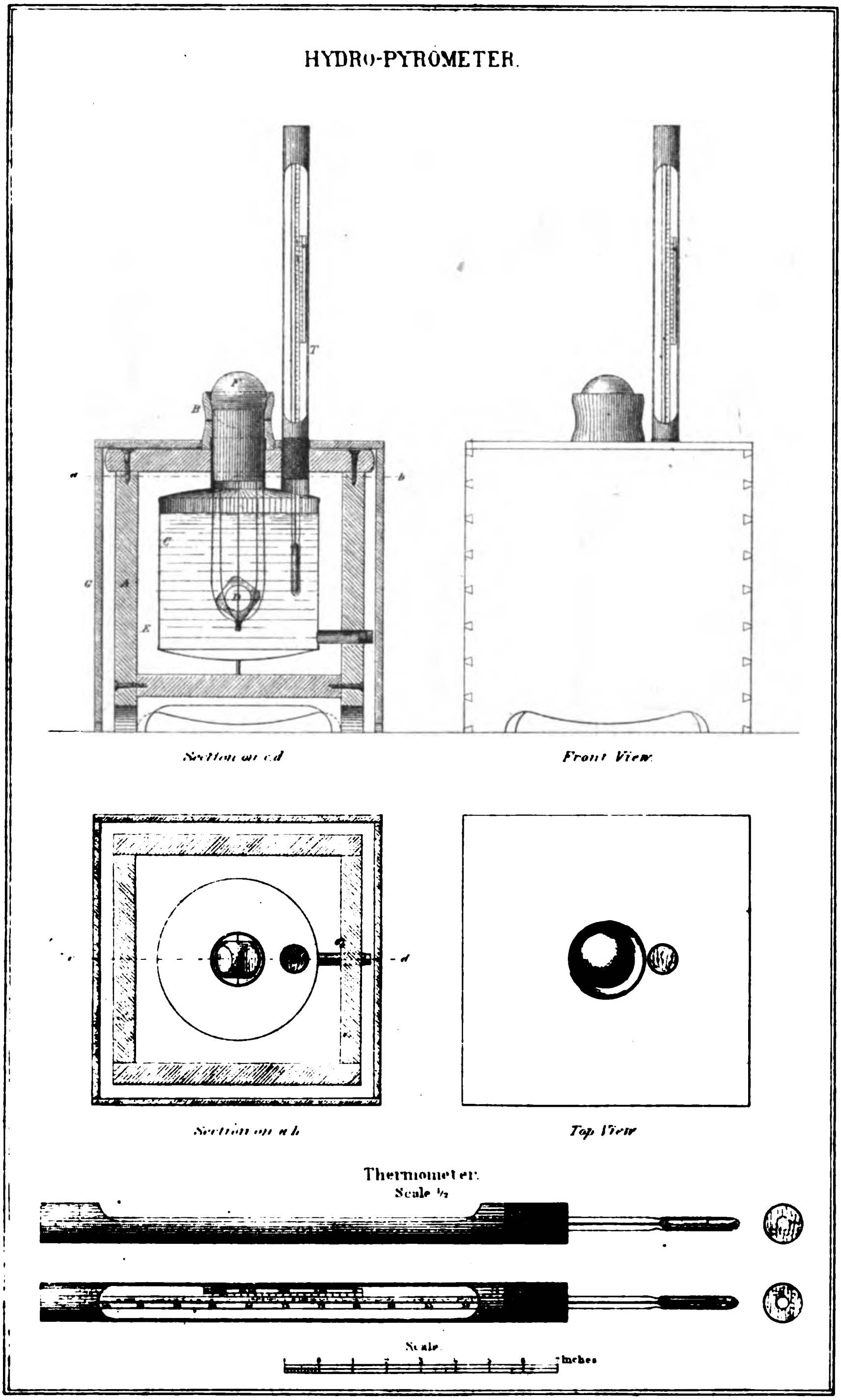


Accompanying Appendix B*. 1878

PLATE III.

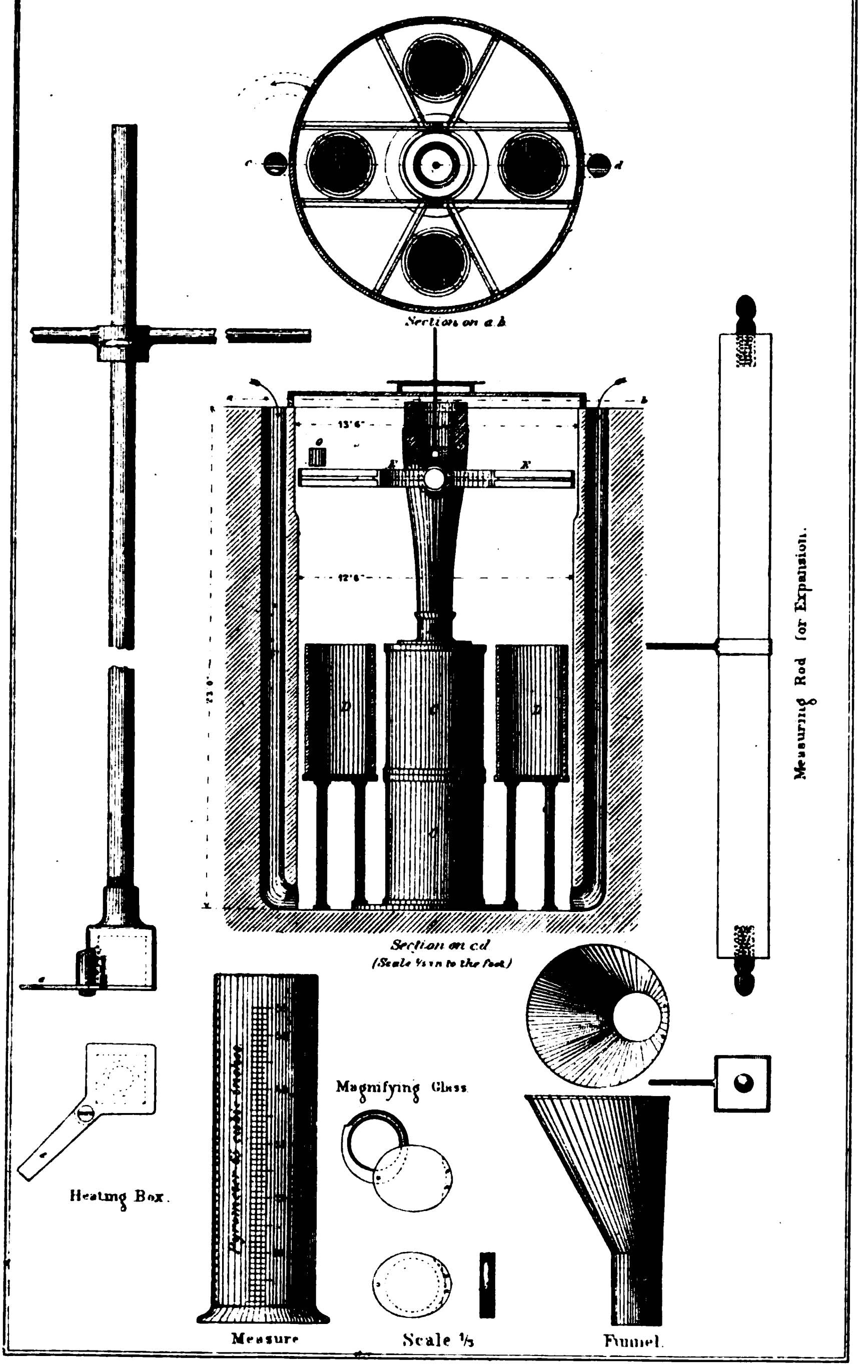


Accompanying Appendix R3, 1878



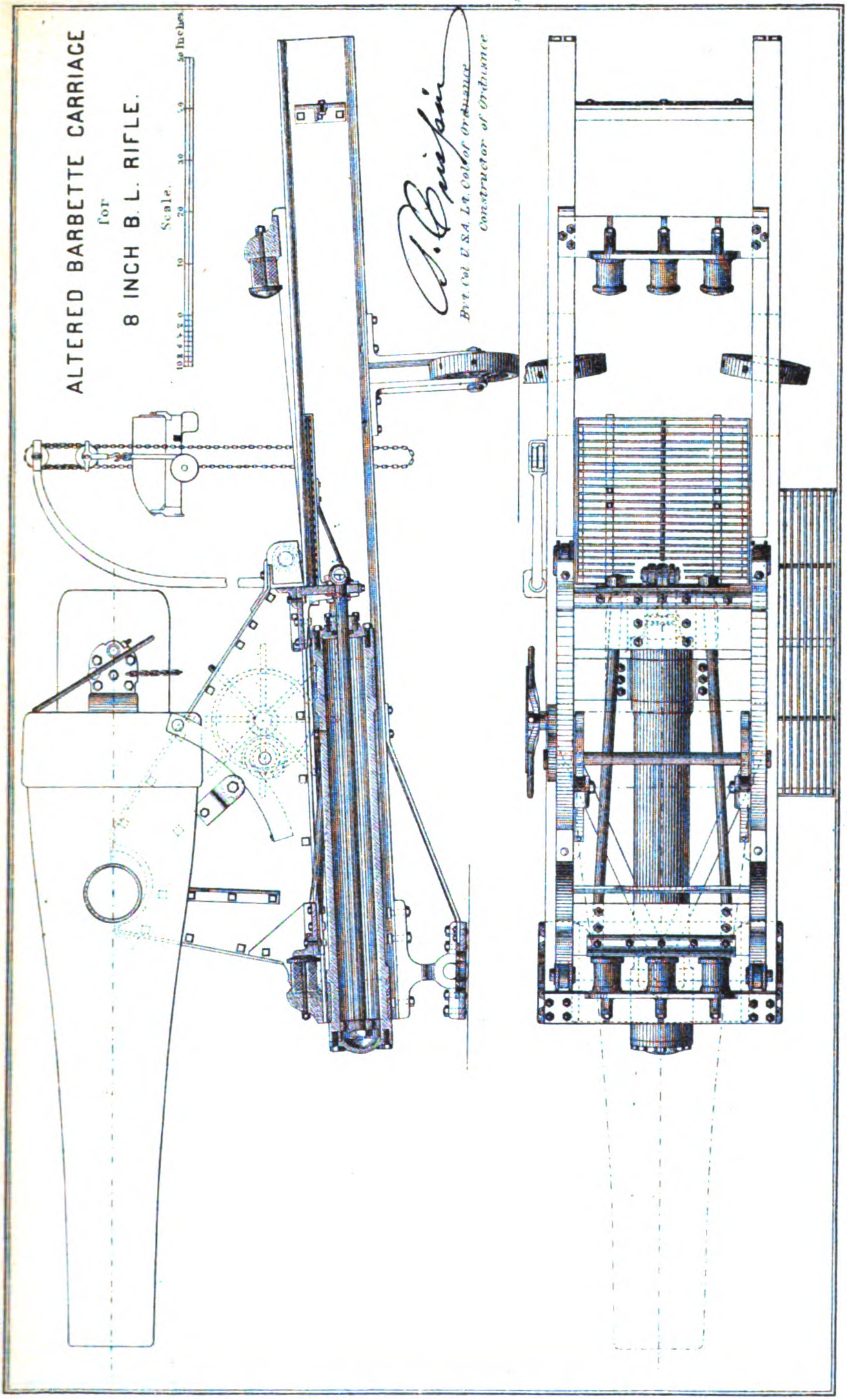
Accompanying Appendix B³. 1878

MODE OF EMPLOYING PYROMETER.



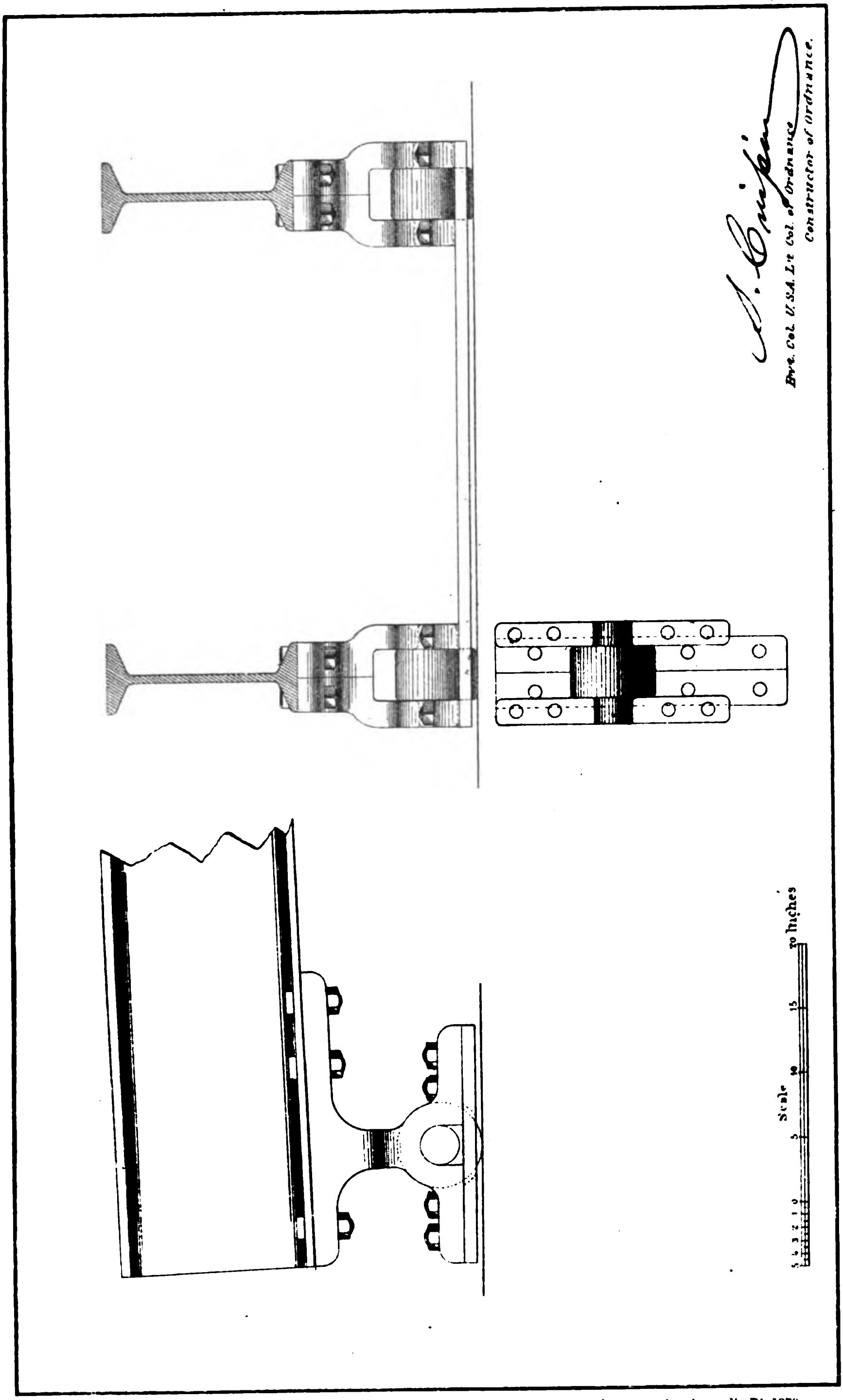
Accompanying Appendix R², 1878

PLATE I.



Accompanying Appendix R⁴, 1878

PLATE II.



Accompanying Appendix R⁴, 1878

APPENDIX S.

Reports of the Ordnance Board, composed of the following officers of the Ordnance Department, viz: Lieut. Col. S. Crispin, brevet colonel, U. S. A.; Lieut. Col. T. J. Treadwell, brevet lieutenant-colonel, U. S. A.; Maj. T. G. Baylor, brevet colonel, U. S. A., and having Capt. F. H. Phipps as recorder, on the trial of guns, projectiles, and fuses.

TRIAL OF THE LOWELL BATTERY GUN, CALIBER .45″, SEPTEMBER AND OCTOBER, 1877, AND APRIL, 1878.

(Twelve plates.)

DESCRIPTION OF THE LOWELL BATTERY GUN, CAL. 0″.45.

THE GENERAL SYSTEM.

(See Plates 1, 2, 3, and 4.)

The Lowell battery, or machine-gun, is of the mitrailleur order. The system is composed of two distinct parts, viz, the barrels, with their disks and trunnions, and the frame and breech, containing the mechanism. The barrels—generally four, although a greater number may be used—are mounted between two supporting disks, arranged to revolve in rings. The ring at center of barrels is provided with trunnions, which work in the frame connecting the barrels with breech mechanism. The rear ring and inclosed disk, when the barrels are in position, lock with the frame. By this arrangement of the barrels they can be disconnected from the breech and tilted up, allowing them to be readily inspected or cleaned; also facilitating the extraction of any obstruction. One of the peculiar features of this gun is that the firing is confined to one barrel at a time, requiring but one lock. This barrel is used until heated, disabled, or clogged, when it is rotated aside by a simple lever-movement and another brought into place, and this can be done quickly and without shutting off the feed. The upper barrel being the one fired, it is always in sight of the operator, and any damage to it, such as bulging or bursting, can be readily detected and its use in subsequent firings avoided.

The breech mechanism is contained in a housing of brass, the lower half of which is securely bolted to the connecting frame, the cover or upper half being secured to it by hinges on the left side and on the right by catches when closed. This cover is in two parts, so that the whole breech mechanism can be exposed, or only that part of it which receives the cartridges from the feeding-tube. The advantage of this arrangement is apparent. In about 15 seconds the cover can be thrown open, and the working parts, which occupy but little space and are exceedingly simple and strong, can be removed and replaced without tools by any man of ordinary capacity. The principal parts of the breech mechanism are, the crank-shaft and worm for rotating feed or carrier rolls; the "lock-plunger" with its firing-pin, firing-pin spring, and two extractors; two carrier-rolls and shafts with gearing, and the feeding-tube. The crank works from the rear, and for purposes of drill or exercise the machinery can be reversed without change. The lock-plunger has two

strong extractors, operating positively and not depending upon springs. These extractors grasp the cartridge-shell on opposite sides and remain locked until the shell is fully withdrawn. The firing-pin has an elongation pointing downward which, as the worm rotates, is forced back by a cam on the worm, compressing the spring. The moment the firing-pin is released, it strikes the primer of cartridge and discharge takes place. The carrier-rolls are simply two cogged wheels, revolving in opposite directions, and so arranged as to receive between their teeth the cartridges delivered from the feeding-tube; the rolls carry the cartridges between plunger and chamber of barrel, receive the fired shell, and, by further movement of crank, force the shells to fall to the ground. One entire revolution of the crank fires and extracts three cartridges. The feeding-tube consists of an upright brass tube, firmly set in a socket directly over the carrier-rolls; it can be removed, if necessary, by loosening a set-screw at its lower end. This tube has a slot on its forward side, extending its whole length, of a width slightly greater than the diameter of the cartridge. It is also slotted on its interior to receive the head of the cartridge, being slightly trumpet-shaped at its top to facilitate the introduction of the cartridge. It will hold about 30 cartridges. In the socket which holds the feeder is a stop with a milled head, normally held back by a spiral spring that allows the cartridge to fall. Should it be desirable to stop the feed, the operator pushes in this "stop," turning it slightly to the left, it being held in that position by a small pin entering a slot. There are also provided for service with the gun feed-cases of tin, holding 17 cartridges each; the cases are made by simply turning a piece of tin about 1 inch wide so as to hold the heads of the cartridges by their flange; pieces of steel bent over the ends of the case and soldered to it hold the cartridges in place.

By placing the case in "feeder" and pressing on the top cartridge, the steel spring is forced back, and cartridges drop into place.

The traversing motion is given by means of an eccentric, the shaft of which is connected by a worm and gearing to the crank-shaft. The eccentric is so arranged that the amount of traverse can be regulated from 0 in degrees upward by the person operating the gun, who can spread or reduce the space covered by his fire according as the object approaches or recedes, increases or diminishes its front, and this without stopping the fire.

CARRIAGE.

(See Plate 4.)

The peculiar features of this carriage are: the U-shaped frame-work which supports the gun on its carriage and which terminates in a ball-and-socket joint, allowing the gun to be moved, by means of a worm working in a section of a rack secured to socket, to the right or left in an arc of a circle; and the device for giving the gun greater elevation and depression than can be obtained by using the elevating-screw alone. The whole frame-work supporting gun rests on an elevating-rack, the arcs of which pass through slots on side rails of trail, pins passing through holes in side rails and arcs, secure the rack.

The elevating apparatus or screw, which in other systems rests upon the trail of carriage, in this case is supported by a projecting arm from the frame-work on which the gun rests, so that the gun, instead of having two points of support on its carriage, has but one—the ball-and-socket joint. The inventors claim as follows: "The mechanism of the carriage

is so arranged that the gun can be leveled, adjusted, or trained to be effective in any position, either at elevation or depression. When operating upon rough or uneven ground and when frequent changes of position are necessary, this arrangement is of much value, as it enables the gunner to bring the gun into any desired position in a very short time. Attached to the carriage are two skeleton cages or crates, where 4,000 cartridges can be deposited and carried with the gun, and at the same time be within easy reach of operator. Three men can work the gun steadily and continuously when this carriage is used. It is manufactured principally of steel and bronze, and is adapted to either Army or Navy use."

RESULTS OF FIRING AT SANDY HOOK, NEW YORK HARBOR.

On the 11th of September, 1877, the gun was fired for initial velocity, using Lowell ammunition, an average of 11 rounds giving 1,266 feet, after which 1,000 rounds were fired testing workings of gun. The following tests were then made for rapidity of fire: 561 rounds fired in 3′ 2¾″; 442 rounds in 2′ 19″; 1,003 rounds in 5′ 2¼″, and 646 rounds in 2′. A delay occurred in firing the 1,003, occasioned by the bursting of a cartridge in the rolls; 357 rounds were afterward deliberately fired in 3′ 21¾″.

A series of 34 cartridges were next fired for rapidity, an average of 10 trials giving 6″; 6,018 cartridges were also fired in 27′ 19½″. (See Appendix A.)

September 14 the gun was fired at a target 52′ by 11′, of 1-inch pine boards, and 200 yards distant; 1,006 rounds fired; all hit (see target appended, Plate 5), the traversing arrangement being set to its full limit of play.

On the 15th of September 1,015 rounds were fired at a similar target 500 yards distant; total number of hits 715 (target appended, Plate 6), the traversing gear being set at about one-half its limit of play. September 20, the gun was again fired 1,000 rounds to test the mechanism.

Up to this time the Lowell ammunition had been exclusively used. With a view of testing other ammunition in the gun, 500 rounds of Bridgeport ammuni ion were fired in 2′ 50″; this ammunition worked well, but not quite as smoothly as the Lowell, this gun being more particularly arranged for the use of a solid-head cartridge.

On the 24th of October the gun was fired deliberately at a target 52′ by 11′, distant 1,000 yards (see target appended, Plate 7), the wind blowing across line of fire with a velocity of 12 miles an hour, the traversing gear being set at 0. Of 1,006 rounds fired there were 497 hits.

In all the tests 14,905 cartridges were fired, 500 of which were made at Bridgeport, the remainder being Lowell solid head. Of the Bridgeport cartridges fired, 6 burst at rim without leak of gas, and 1 burst in body. None failed to explode.

Of the Lowell, 14 burst in body, and in 25 there was escape of gas at cap; 29 failed to explode, 13 of which number had no fulminate. The remaining 16 exploded in Springfield rifle, first blow. During the firings, 3 cartridges burst in rolls, which is to be attributed to the following cause: When changing barrels so as to bring another into use, the lever and spring did not bring the fresh barrel exactly into line with the jaws of the rolls, so that when the cartridge was pressed forward the bullet caught in the barrel and jammed there, and cartridge was exploded by pressure of block behind it.

DISCUSSION OF THE SYSTEM.

GUN.

The principal features of this gun, different from those used in other systems, are the feed, the double extractor, and the accessibility of parts—features possessing much merit. The carrier-rolls prevent the accumulation of cartridges before the lock, receive the shells as they are withdrawn from the barrel and carry them clear of the gun, all their movements being positive and certain. The extractors, from the construction of the "lock-plunger," are obliged to retain hold of the flange of the cartridge until the shell is delivered to the rolls, clear of the barrel. The working parts of the gun being so accessible can be quickly removed for repairs or cleaning, and, in case the gun should have to be abandoned in the field, can be readily disabled by removal of mechanism. The only parts liable to disarrangement or that generally require cleaning are the "lock-plunger" and the two "carrier-rolls."

The barrels, not being made fast to the frame-work, can be "tilted up," making inspection and cleaning an easy operation, but a want of stability and a sacrifice of accuracy result.

CARRIAGE.

The carriage submitted with the gun has so much play in the ball-and-socket joint, the circular elevating-rack, and elevating-screw as to impair the accuracy of fire, more especially at long ranges, so necessary for army uses. The trail itself is not sufficiently strong or rigid to prevent springing under fire.

All these features, however, are remediable, and in subsequent firings, which it is desirable should be made with the gun, a different carriage ought to be used, in order that the merits of the *gun system* may be more fully tested.

ACCURACY OF FIRE.

It will be observed from the records of firing that at 200 yards all of the 1,006 rounds fired hit target; at 500 yards there were 715 hits for 1,015 rounds; and at 1,000 yards 497 hits out of 1,006 rounds fired. In the last case the wind blew directly across the line of fire with a velocity of 12 miles an hour. An examination of the target plottings (Plates 5, 6, and 7) shows for 200 yards the greatest number of hits at the extreme right and left of target, indicating a slight loss of motion of traversing gear at extreme limits of oscillation. At 500 yards the shots were fairly distributed over target within limits of oscillation, the traversing gear being set at half its limit only.

At 1,000 yards (oscillator not used) the want of accuracy due to vibration of barrels becomes more apparent, as might be expected. The results at 500 and 1,000 yards are not as good as those obtained with other mitrailleur systems, but this is due principally to defects in carriage, which have been heretofore explained.

RAPIDITY OF FIRE AND NUMBER OF MEN REQUIRED TO WORK THE GUN.

In all the firings at Sandy Hook there were three men at the gun, one at crank and two supplying the cartridges, which were fed from feed-cases holding 17 rounds, the feed-cases being filled in advance of the firing. Two men are sufficient to work the gun if filled feed-cases are

near at hand, although with three men a more rapid firing is assured. The greatest rapidity was attained in firing 340 rounds in 1′ ¼″.

CONCLUSIONS.

As far as the system in its present shape is concerned, the Board has decided that no additional tests are necessary to be made now; but, in view of the simplicity of the gun, the smoothness and regularity of the workings of the different parts (few in number), and the general satisfactory results attained in the present firings, the Board deems it important that additional trials be made, only, however, after modifications are introduced in the system as presented, having in view more especially the increasing of the accuracy of fire and correcting other imperfections for army uses.

In the opinion of the Board, the system should (if fully practicable) admit of the use of all makes of ammunition, and the carriage must be so modified as to insure greater accuracy of fire.

RECOMMENDATIONS.

The Board recommends that a new gun be made for trial, embodying any improvements deemed practicable and desirable by the inventor, but more especially those looking to the insuring of increased accuracy of fire and increased stability of the system; the gun and carriage to be ordered by the department, and the Board to be consulted as to general features and details of the system.

APPENDIX A.

Record of firing with Lowell battery gun, caliber .45″, at Sandy Hook, New York Harbor, from September 11 to October 24, 1877.

Time.	Ammunition.	Number of cartridges fired.	Time.	Total number of cartridges fired.	Total time.	Initial velocity.	Time occupied in firing 1,003 rounds, or 59 feed-cases of 17 each.	Remarks.
1877.			′ ″		′ ″	*Feet.*	′ ″	
Sept. 11	Lowell..	1	......			1,255	....	
11	...do	1	......			1,249	....	
11	...do	1	......			1,222	....	
11	...do	1	......			1,238	....	
11	...do	1	......			1,247	....	
11	...do	1	......	11	......	1,213	....	Fired into sand-butt for velocities
11	...do	1	......			1,340	....	
11	...do	1	......			1,328	....	
11	...do	1	......			1,328	....	
11	...do	1	......			1,253	....	
11	...do	1	......			1,252	....	
11	...do	1,000	......	1,000	......	....	....	Fired into sand-butt to try mechanism of gun.
11	...do	221	1					
11	...do	170	1	561	3 2¾	....	....	Fired into sand-butt for rapidity.
11	...do	170	1 2¼					
11	...do	136	1					
11	...do	204	1	442	2 19	....	....	Do.
11	...do	102	19					
11	...do	34	7¼					
11	...do	34	6¼					
11	...do	34	6½					
11	...do	34	6					
11	...do	34	5¾	340	1 ¼	....	....	Do.
11	...do	34	5½					
11	...do	34	5½					
11	...do	34	6					
11	...do	34	5¾					
11	...do	34	5¼					
11	...do	221	1					
11	...do	255	1					
11	...do	255	1	1,003	5 2¼	....	....	Do.
11	...do	204	1					
11	...do	68	1 2¼	......	......	....	....	Delay caused by a cartridge bursting in rolls.

Record of firing with Lowell battery gun, &c.—Continued.

Time.	Ammunition.	Number of cartridges fired.	Time.	Total number of cartridges fired.	Total time.	Initial velocity.	Time occupied in firing 1,003 rounds, or 59 feed-cases of 17 each.	Remarks.
1877.			′ ″		′ ″	*Feet.*	′ ″	
Sept. 11	...do	323	1	646	2	....	....	Fired into sand-butt for rapidity.
11	...do	323	1					
11	...do	357	3 21½	357	......	....	....	Fired into sand-butt deliberately.
11	...do	255	1					
11	...do	238	1					
11	...do	255	1					
11	...do	238	1					
11	...do	221	1					
11	...do	680	4					
11	...do	136	1					During this 6,018 rounds a cartridge jammed between barrel and rolls, due to making a change of barrels improperly.
11	...do	238	1					
11	...do	221	1					
11	...do	204	1	......	......	....	4 15	Fired into sand-butt for rapidity and to test endurance of gun.
11	...do	255	1	......	......	....	5 00	
11	...do	204	1	6,018	27 19½	....	4 40	
11	...do	272	1	......	......	....	4 23	
11	...do	238	1	......	......	....	4 22	
11	...do	272	1	......	......	....	4 39½	
11	...do	289	1					
11	...do	204	1					
11	...do	255	1					
11	...do	255	1					
11	...do	238	1					
11	...do	221	1					
11	...do	221	1					
11	...do	136	1					
11	...do	238	1					
11	...do	34	19½					
14	...do	1,006	......	1,006	......	....	....	One cartridge burst in rolls; bullet found in housing of mechanism after trial was over, not interfering with working of mechanism during trial. Fired at 200-yard target for accuracy (see target appended, Plate 5); number of hits in target, 1,006.
15	...do	1,015	......	1,015	......	....	....	Fired at 500-yard target for accuracy (see target appended, Plate 6); number of hits in target, 715.
20	...do	1,000	......	1,000	......	....	....	Fired to test mechanism of gun.
21	Berdan .	500	......	500	2 50	....	....	Fired into sand-butt.
Oct. 24	Lowell..	1,006	......	1,006	......	....	....	Firing deliberate, time not taken; wind 12 miles per hour across line of fire; fired at 1,000-yard target; number of hits in target, 497 (see target appended, Plate 7); one cartridge burst in rolls, seven cartridges failed to explode, six of which exploded in Springfield rifle; one had no priming. Bursting of cartridge in rolls attributed to the following cause: when changing barrels so as to bring another into use, the lever and spring did not bring the fresh barrel exactly into line with the jaws of the rolls, so that when the cartridge was pressed forward the bullet caught in the barrel and jammed there, and cartridge was exploded by pressure of block behind it; upon opening housing of mechanism afterwards, two cartridges were found jammed in the same jaw of the rolls, the barrel not being in line with the jaws of the rolls, preventing turning the crank.
	Total ..	14,905	......	14,905	......	....	....	

WORKINGS OF CARTRIDGES.

Of the Bridgeport cartridges fired, 6 burst at rim without leak of gas, and one burst in body. None failed to explode.

Of the Lowell, 14 burst in body, and in 25 there was escape of gas at cap; 29 failed to explode, 13 of which number had no fulminate; the remaining 16 exploded in Springfield rifle, first blow.

The Board, in its report of November 8, 1877, on the Lowell battery gun, recommended "that a new gun be made for trial embodying any improvements deemed practicable and desirable by the inventor, but more especially those looking to the insuring of increased accuracy of fire, and increased stability of the system; the gun and carriage to be ordered by the department, and the Board to be consulted as to the general features and details of the system."

The Board was induced to make these recommendations in consequence of a want of stability developed in the firings with the gun and carriage submitted, particularly in the ball and socket joint, by means of which the gun was connected with its carriage.

This recommendation of the Board having been approved, and a gun and carriage ordered by the Chief of Ordnance under date of November 19, 1877, the Board, after consultation with the Lowell Gun Company, decided upon the details, &c., which were carried out.

In the matter of a carriage, the Board decided to mount the gun upon a 6-pounder field carriage to be selected from any on hand in the department.

GUN.

The gun itself is in general features the same as that described in the report of the Board of November 8, 1877. It differs from it in the following particulars only: The size of barrels have been increased from $1\frac{3}{16}''$ to $1\frac{7}{16}''$ diameter; the breech-block, which was $1\frac{1}{16}''$ thick, is now $1\frac{5}{16}''$; the barrel supports have been increased from $\frac{13}{16}''$ and $\frac{1}{2}''$ in thickness to $1''$ and, $1\frac{1}{2}''$, respectively, and the diameter of same increased to correspond to increased diameter of barrels. The side bars have been increased in size and strength, and the trunnions moved from their former position, 6 inches to the front, bringing them directly over the axle. The barrel trunnion plate has also been moved forward about $2''$. A slight change has also been made in the cocking plate, to obviate danger from premature explosions. These changes are shown on Plate VIII accompanying. The weight of gun without carriage is 215 pounds.

CARRIAGE.

The desire of the Board being to test simply the gun, it was decided to put it upon a stable carriage, dispensing with ball and socket joint, and connecting as in the "Gatling." A 6-pounder field gun was therefore procured from Watervliet arsenal and sent to Chicopee, that the Lowell Gun Company might attach the gun to it. To prevent the elevating screw from turning during firing, a clamp was attached through the trail, by means of which, when the proper elevation has been given, the screw is firmly held. (Plate IX.)

RESULTS OF FIRING AT SANDY HOOK.

On the 9th of April, 1878, the gun was fired deliberately, five series of 1,003 rounds each, into a sand-butt, to test the mechanism of the gun. During this firing the extractor tore through the rims of 3 cartridges,

failing to extract them, but they were readily removed by tipping the barrels on their trunnions, and introducing a rammer from the front. During the second series the barrels were changed twice, in the remainder but once. The average time lost in changing the barrels was about 17″, and the average time occupied in firing each series of 1,003 rounds, less the delays above referred to, was 4′ 43$\frac{1}{5}$″.

To test the rapidity of fire, six series were fired, the greatest number fired in any single minute being 368 cartridges, an average of the four even minutes giving 332 cartridges fired per minute; these four series were fired by different men doing their best.

The gun was then fired at targets 52′ by 11′ made of 1′ spruce boards, at distances of 200, 500, and 1,000 yards, with the following results:

At the 200-yard target 1,007 shots in all were fired. Total hits 1,004, miss fires 3, with oscillator set at full play. (Plate X.)

At the 500-yard target, total shots 1,003, total hits 832, miss fires 10. During the firing at this target the oscillator, which was set at half its play, worked loose, and the latter half of the series was fired with the gun at full traverse. (Plate XI.)

At the 1,000-yard target, total shots 1,003, total hits 605, of which 518 were direct and 87 ricochet, miss fires 20. The traversing mechanism was set so as to allow of no play (Plate XII). An average of 10 shots gave a velocity of 1,298 feet per second.

In all 10,044 cartridges of Frankford Arsenal manufacture were fired with but one failure due to the ammunition, which was caused by the absence of vent holes in cup anvil.

There were in all the firings 60 miss fires in the gun, all of which exploded in Springfield rifle on first trial except 4, 3 of which exploded on second trial, and the other being the one above referred to as having no vents in cup anvil.

Comparing the results shown above with those obtained in September and October last, and reported upon November 8, 1877, it will be seen that the last average velocity is greater by 32 feet; that the rapidity of fire is about the same. The accuracy is better than that obtained in September and October last at 500 and 1,000 yards, as will be seen by an examination of the following table:

Target.	Firing of September and October, 1877.			Firing of April, 1878.		
	Total shots.	Total hits.	Miss fires.	Total shots.	Total hits.	Miss fires.
200-yard target	1,006	1,006	....	1,007	1,004	3
500-yard target	1,015	715	....	1,003	832	10
1,000-yard target	1,006	497	7	1,003	605	20

The board, in concluding, find that in consequence of the alterations made in the gun its accuracy and efficiency have been improved, particulary at 500 and 1,000 yards; that the gun is more readily worked and is now capable of using any metallic ammunition. The imperfection noted in regard to the oscillator when firing at 500-yard target the board does not deem of any importance, as it can be readily corrected in future constructions.

RECOMMENDATIONS.

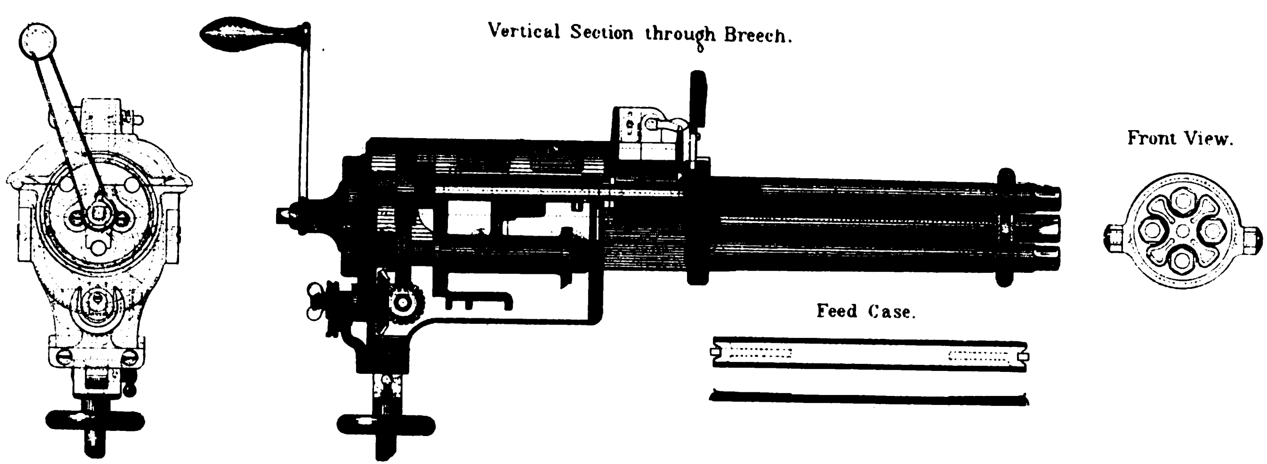
In view of the favorable results of the trials at Sandy Hook, the board recommends that a number deemed sufficient by the department

of the .45″ caliber guns be procured from the Lowell Gun Company, with all the latest improvements, and sent to Watervliet Arsenal to be mounted on gun-carriages adapted for them, and that the guns and carriages suitably equipped be put in the field for comparison with other machine guns now on trial in service.

Record of firing with Lowell battery gun, caliber .45″, at Sandy Hook, April 9, 17, 18, and 20, 1878.

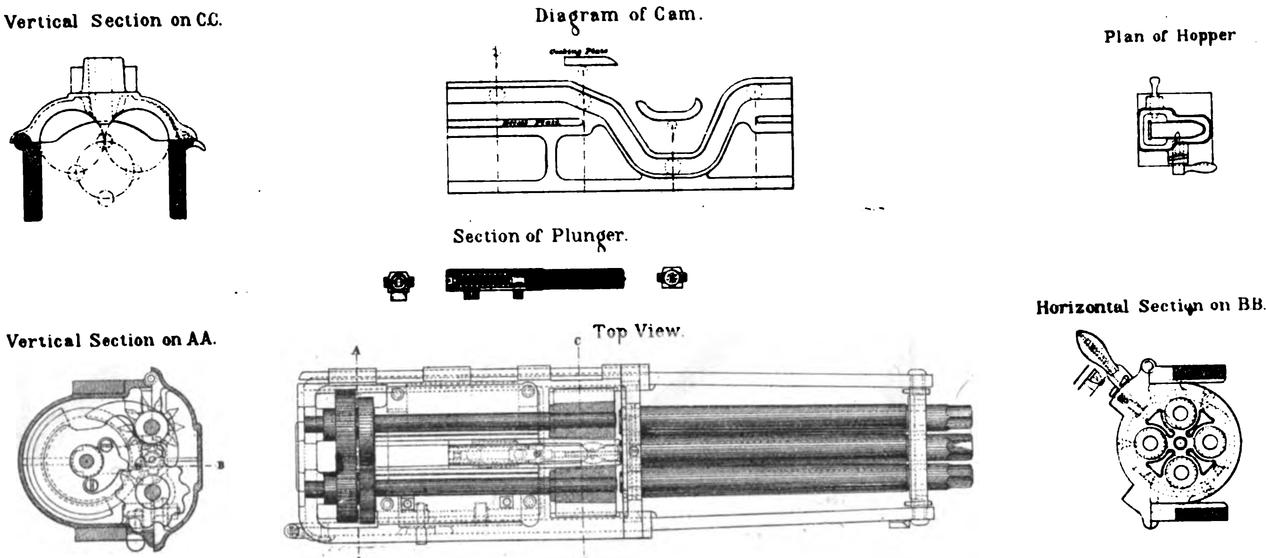
Time.	Ammunition.	Number of cartridges fired.	Total time.	Delays.	Time, less delays.	Velocities.	Remarks.
1878.			′ ″	′ ″	′ ″		
April 9	Frankford	1,003	5 4	4	5	....	These 5 series of 1,003 each were deliberately fired into sand-butt to test mechanism of gun. In the 4th and 5th series the extractor tore through the rims of 3 cartridges, failing to extract them, causing, with the time occupied in shifting barrels, the delays noted. The barrels were shifted only once in all the series except the second, when they were changed twice.
9	....do	1,003	5 19	35	4 44	....	
9	....do	1,003	5 10	13	4 57	....	
9	....do	1,003	7 25	3 5	4 20	....	
9	....do	1,003	6 50	2 15	4 35	....	
9	....do	312	1	......	......	....	Fired into sand-butt to test rapidity o firing.
9	....do	294	1	......	......	....	
9	....do	30	4½	......	......	....	
9	....do	354	1	......	......	....	
9	....do	368	1	......	......	....	
9	....do	648	2 15	......	......	....	In the first 11 series 27 failed to explode, 6 of which were run through gun second time, not exploding; all but one exploded in Springfield rifle; failure of latter due to there being no vent holes in cup anvil.
9	....do	1,007	6 27	......	......	....	Fired at 200-yard target. Total number of hits, 1,004; 3 miss fires; all exploded on first trial in Springfield. Cams oiled once, and barrels not cleaned during above firing.
17	....do	1,003	......	......	......	....	Fired at 500-yard target. Total number of hits, 832; 10 miss fires. The traversing mechanism was set so as to allow the barrels to traverse only half its limits. After firing about 600 rounds the set screw worked loose, and the remaining rounds were fired with gun working full traverse. Of the ten miss fires all exploded on first trial in Springfield rifle.
18	....do	1,003	......	......	......	....	Fired at 1,000-yard target. Total number of hits, 605; direct hits, 518; ricochet hits, 87; 20 miss fires. The traversing mechanism was set so as not to allow of any traverse. Of the 20 miss fires all but 3 exploded on first trial in Springfield rifle; these 3 exploded on second trial.
20	....do	1	......	......	......	1,316	Fired in sand-butt for velocity.
20	....do	1	......	......	......	1,290	
20	....do	1	......	......	......	1,313	
20	....do	1	......	......	......	1,290	
20	....do	1	......	......	......	1,303	
20	....do	1	......	......	......	1,281	
20	....do	1	......	......	......	1,305	
20	....do	1	......	......	......	1,290	
20	....do	1	......	......	......	1,296	
20	....do	1	......	......	......	1,298	

LOWELL BATTERY GUN.



The Ordnance Board convened under orders of
the War Dept S. O. No 129 of June 27, 1876.
Frank K. Phipps.
Capt of Ordnance.
Recorder.

LOWELL BATTERY GUN.

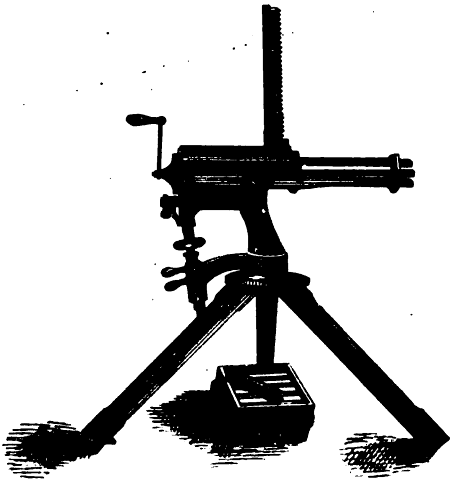


The Ordnance Board convened under orders of the War Dept S.O. No 129 of June 27, 1876

Frank H. Phipps
Capt of Ordnance,
Recorder.

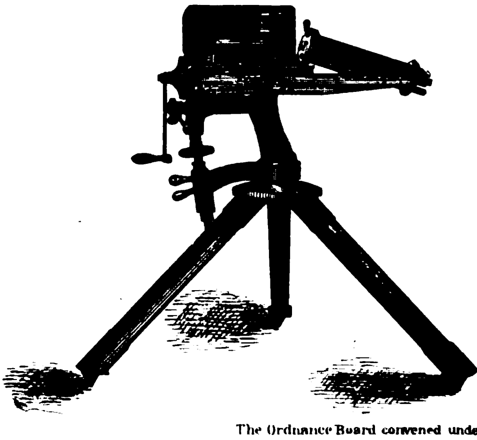
LOWELL BATTERY GUN,

Mounted on a Tripod



LOWELL BATTERY GUN,

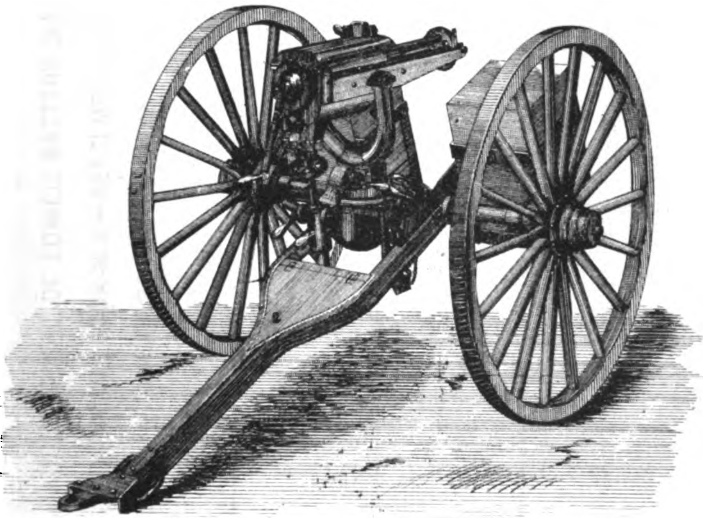
Thrown open for Inspection.



The Ordnance Board convened under orders of
the War Dept S. O. Nº 129 of June 27, 1876.
Frank H. Phipps
Capt of Ordnance,
Recorder

LOWELL BATTERY GUN,

and Field Carriage.



The Ordnance Board convened under orders of
the War Dep't S.O. Nº 129 of June 27, 1876.

Frank K. Phipps.
Capt of Ordnance,
Recorder.

Accompanying Appendix 8, 1878

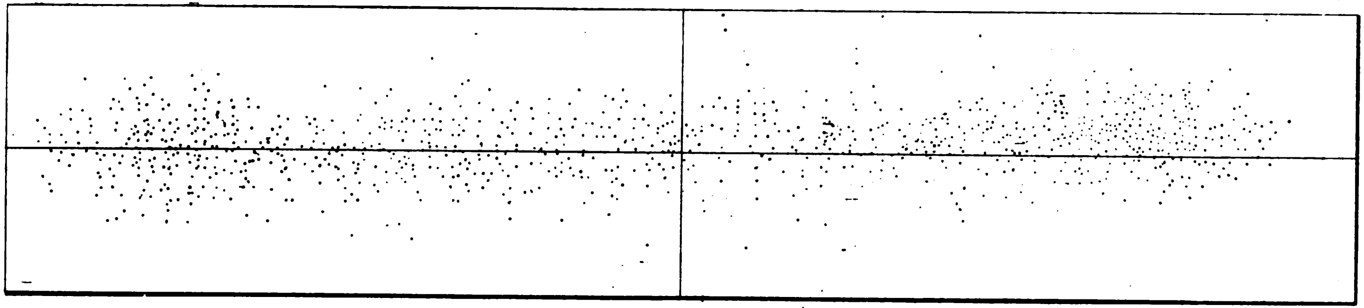
TARGET RECORD OF LOWELL BATTERY GUN CAL.45

AT SANDY HOOK N.J.— SEPTEMBER 14th 1877.

TARGET 200 YARDS FROM GUN.

Nº OF ROUNDS FIRED 1006.

Nº OF HITS 1006.



TARGET 52 × 11 ft. MADE OF 1 in PINE BOARDS.—

The Ordnance Board convened under orders of
the War Dept S.O. Nº 129 of June 27, 1876.
Frank H. Phipps.
Capt of Ordnance,
Recorder.

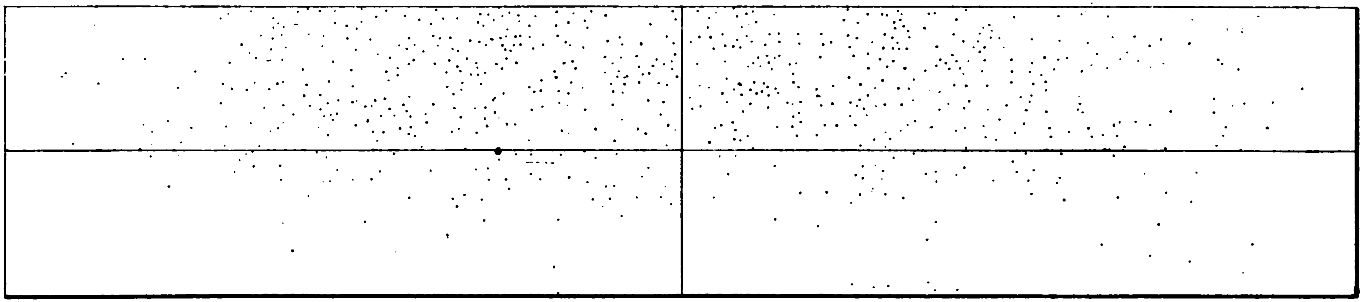
TARGET RECORD OF LOWELL BATTERY GUN CAL. .45

AT SANDY HOOK N.J. — SEPTEMBER 15th 1877.

TARGET 500 YARDS FROM GUN.

Nº OF ROUNDS FIRED 1015.

Nº OF HITS 715.



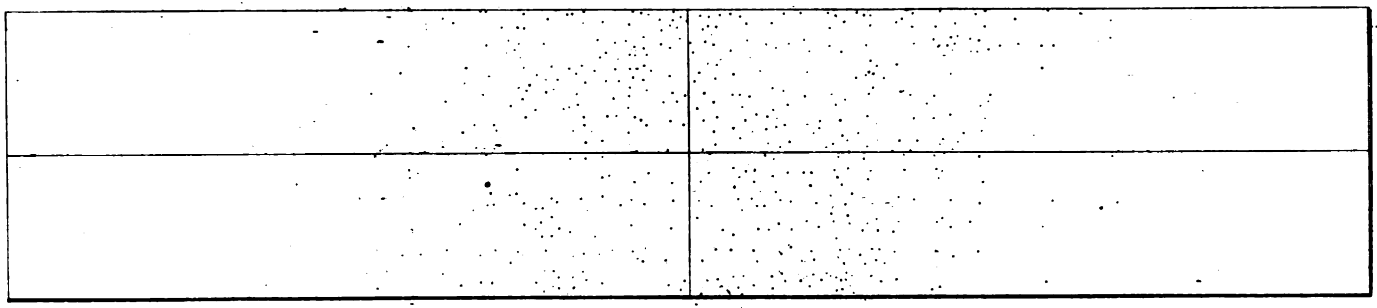
TARGET 52×11 ft. MADE OF 1in PINE BOARDS.

The Ordnance Board convened under orders of
the War Dept S. O. Nº 129 of June 27, 1876
Frank H. Phipps
Capt of Ordnance,
Recorder.

PLATE VII.

TARGET RECORD OF LOWELL BATTERY GUN CAL.45
AT SANDY HOOK N.J.—OCTOBER 24th 1877.
TARGET 1000 YARDS FROM GUN.

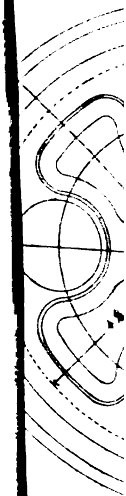
Nº OF ROUNDS FIRED 1006. Nº OF HITS 497.



TARGET 52×11ft. MADE OF 1in PINE BOARDS.

The Ordnance Board convened under orders of
the War Dept S.O.Nº 129 of June 27 1876
Frank H. Phipps
Capt of Ordnance
Recorder.

Accompanying Appendix 8, 1878



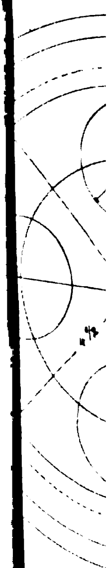
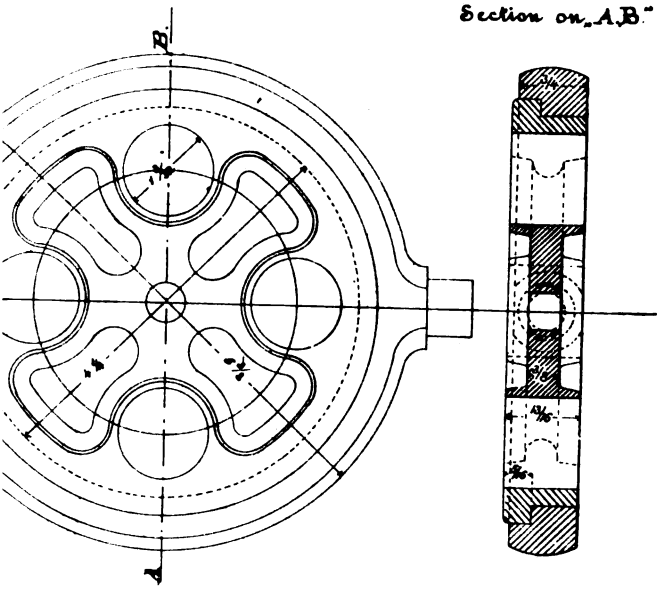
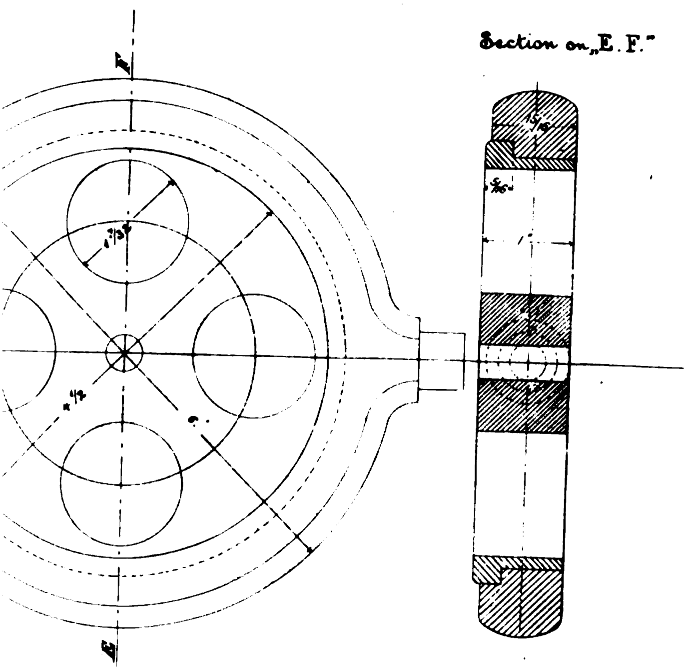


PLATE VIII.

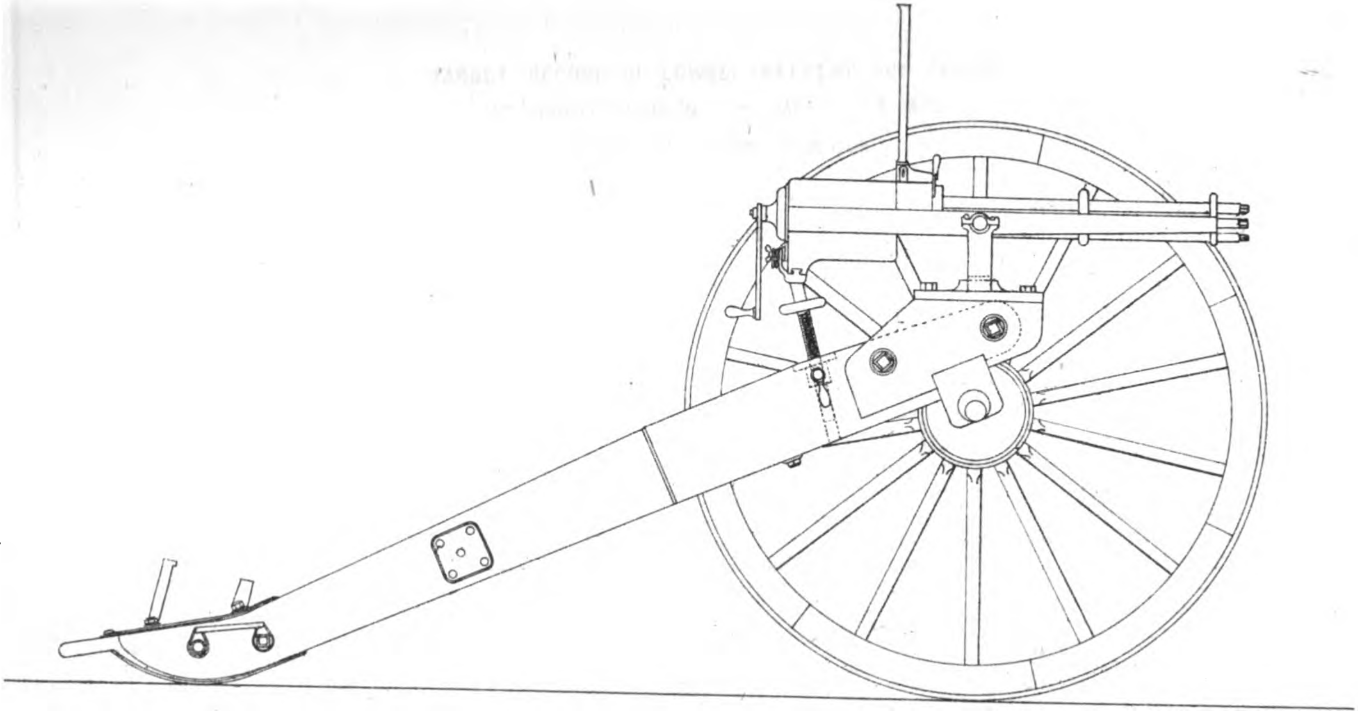
Section on „A.B."



Section on „E. F."



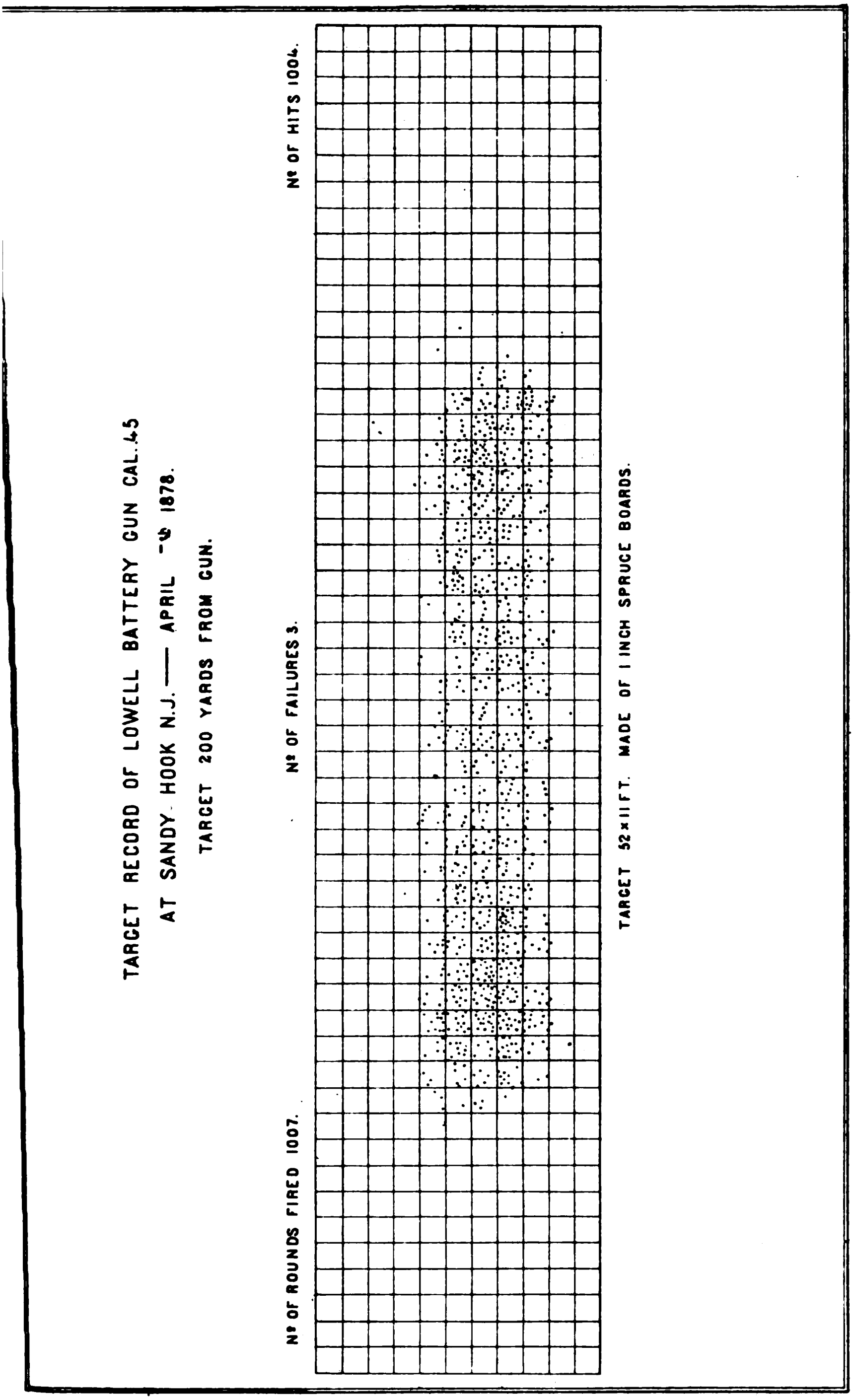
Gatling Gun mounted on Field Carriage.



Frank C. Phipps.
Capt. of Ord.
Recorder.

PLATE IX.

Accompanying Appendix 8, 1878

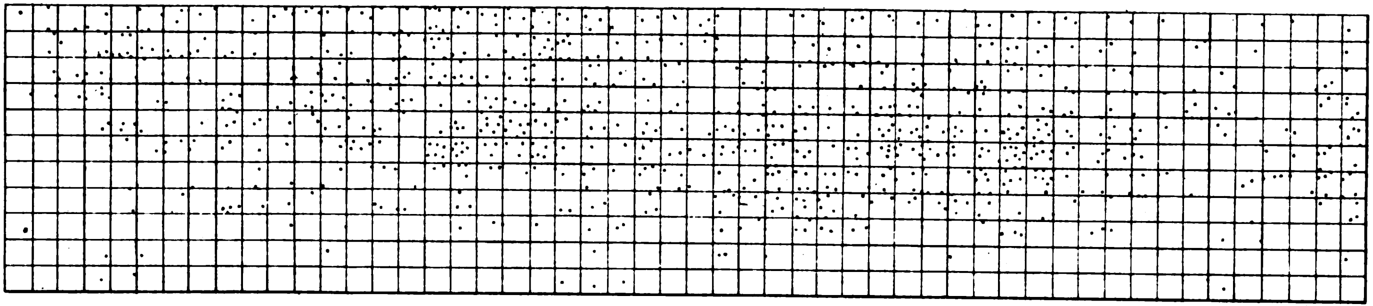


Accompanying Appendix 8, 1878

TARGET RECORD OF LOWELL BATTERY GUN CAL. .45
AT SANDY HOOK N.J. —— APRIL 17th 1878.
TARGET 500 YARDS FROM GUN.

Nº OF ROUNDS FIRED 993.

Nº OF HITS 832.



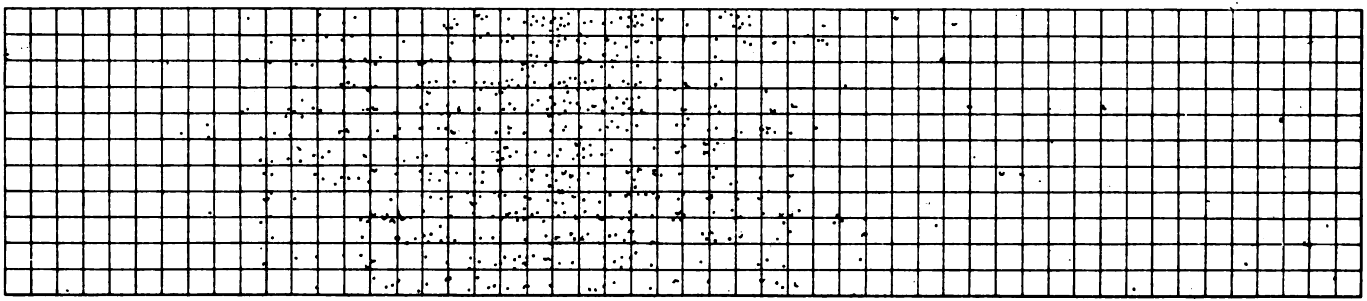
TARGET 52 × 11 FT. MADE OF 1 INCH SPRUCE BOARDS.

TARGET RECORD OF LOWELL BATTERY GUN CAL. 45

AT SANDY HOOK N.J. —— APRIL 18th 1878.

TARGET 1000 YARDS FROM GUN.

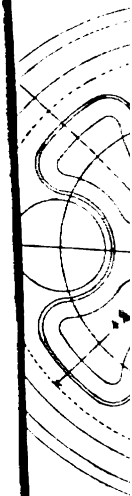
Nº OF ROUNDS FIRED 983. Nº NOT THROUGH 87 Nº OF DIRECT HITS 618



TARGET 52 × 11 FT. MADE OF 1 INCH SPRUCE BOARDS.

Direct Hits are represented thus .... •

Hits not through are represented thus.. ^



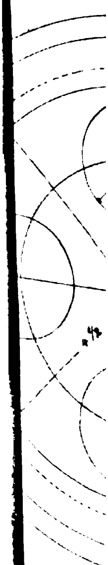
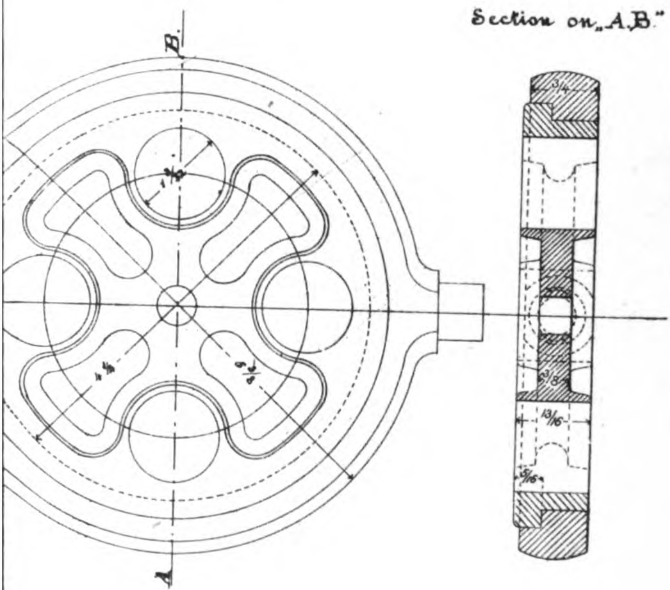


PLATE VIII.

Section on „A.B."



Section on „E. F."

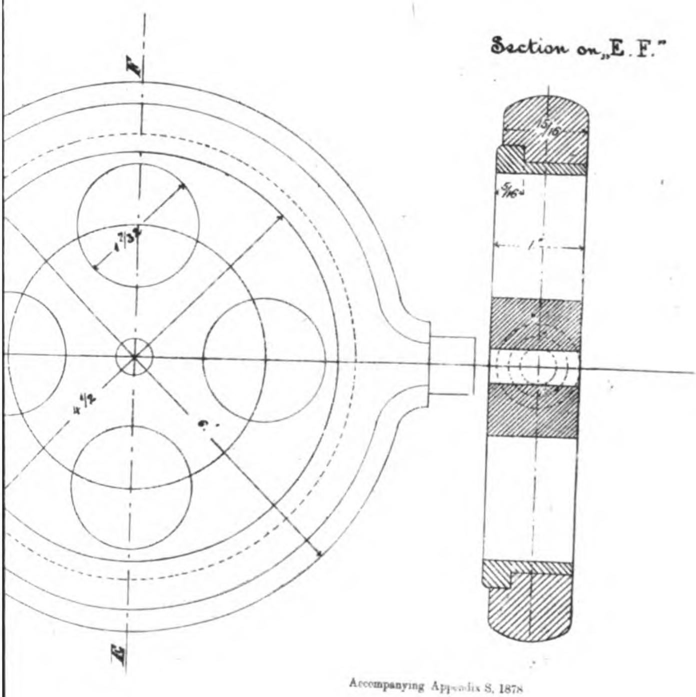
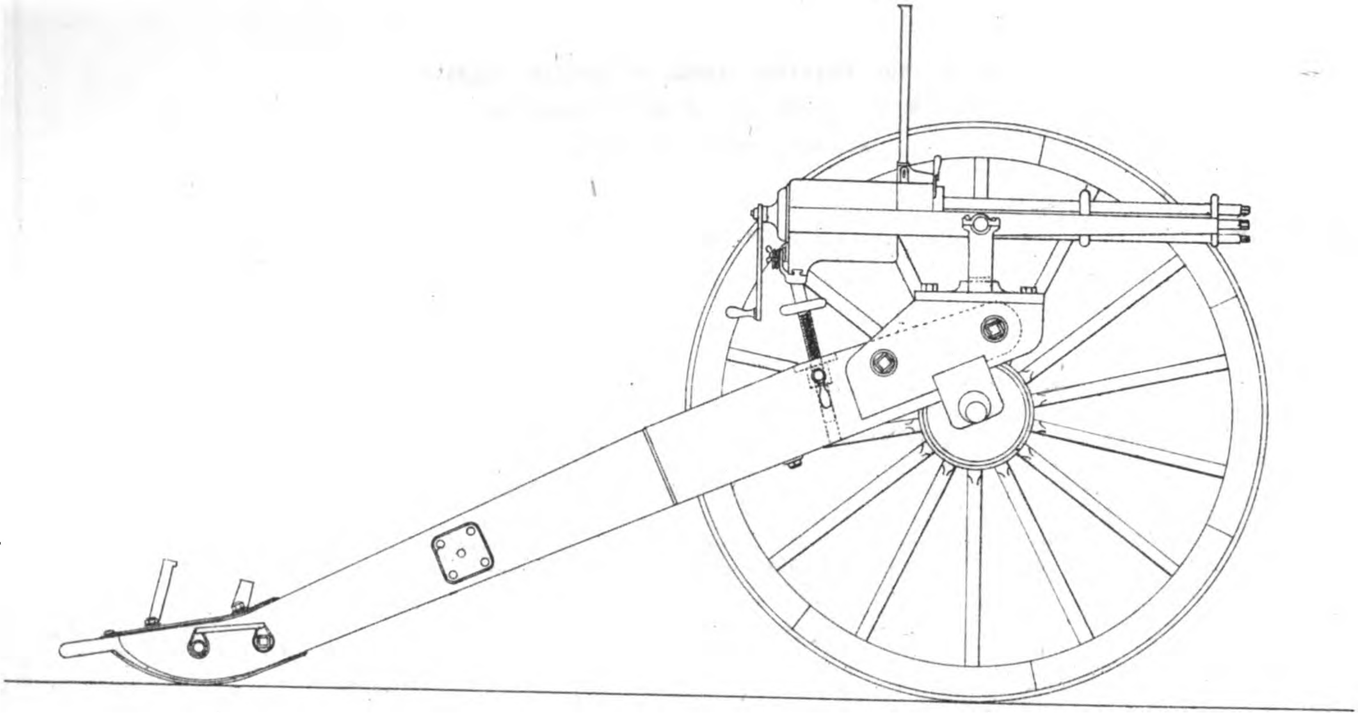


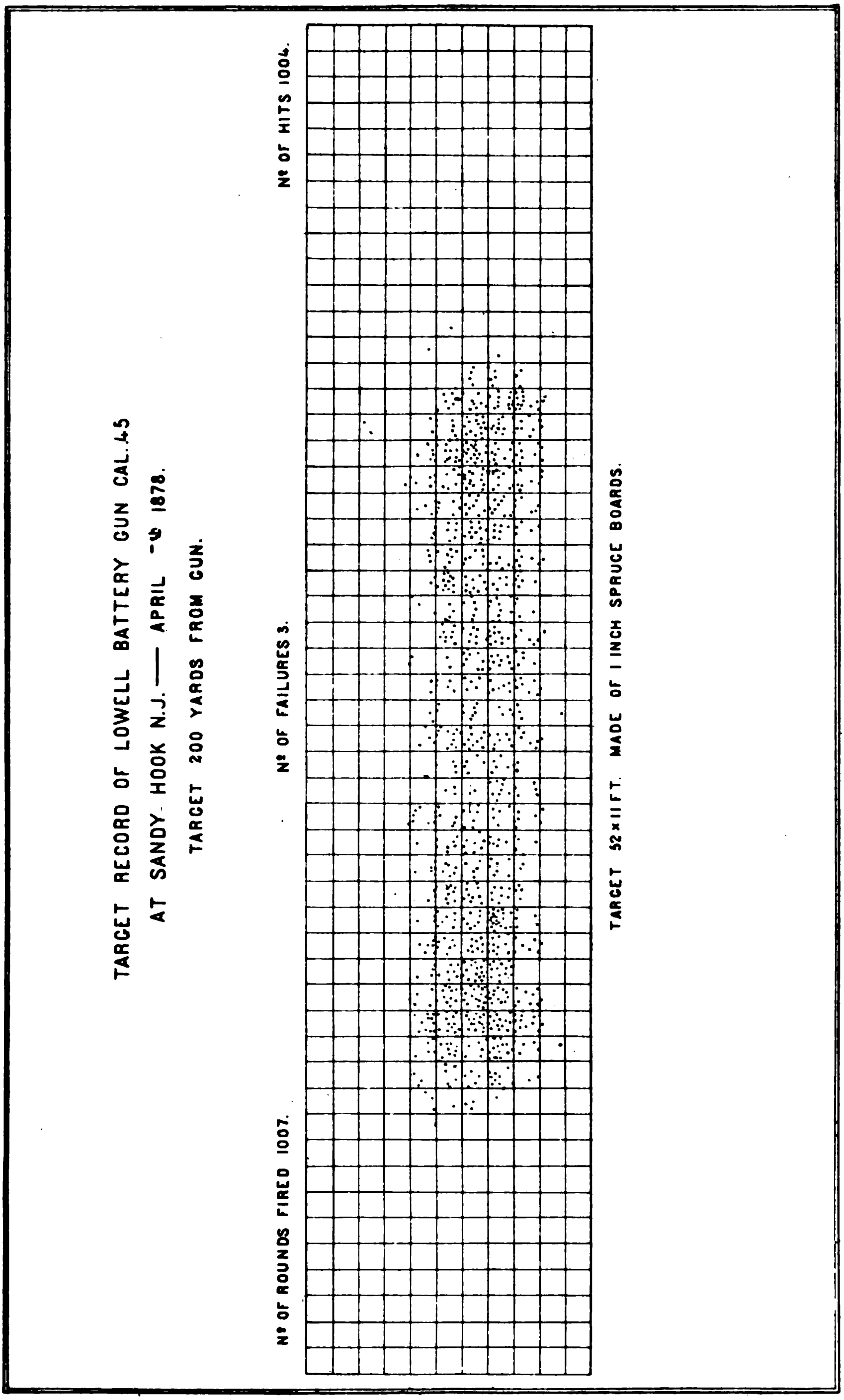
PLATE IX.

Battery Gun mounted on Field Carriage.



Frank H. Phipps.
Capt Ord
Recorder.

Accompanying Appendix 8, 1878



Accompanying Appendix 8, 1878

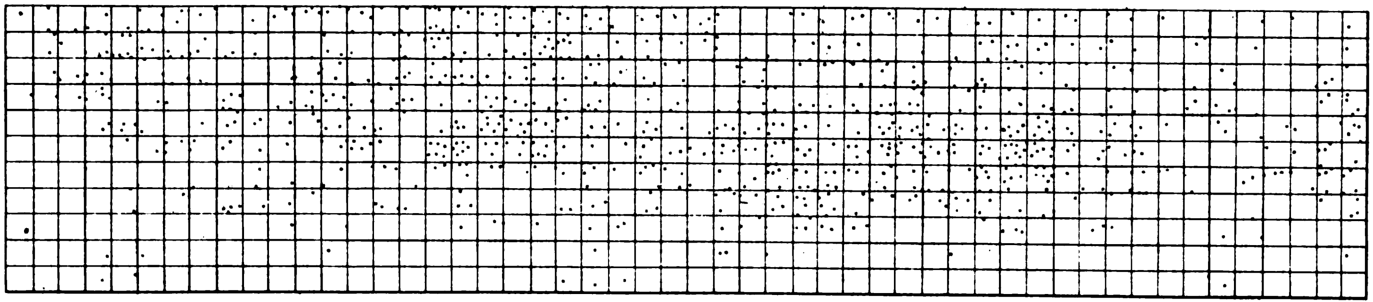
TARGET RECORD OF LOWELL BATTERY GUN CAL. .45

AT SANDY HOOK N.J. —— APRIL 17th 1878.

TARGET 500 YARDS FROM GUN.

Nº OF ROUNDS FIRED 993.

Nº OF HITS 832.



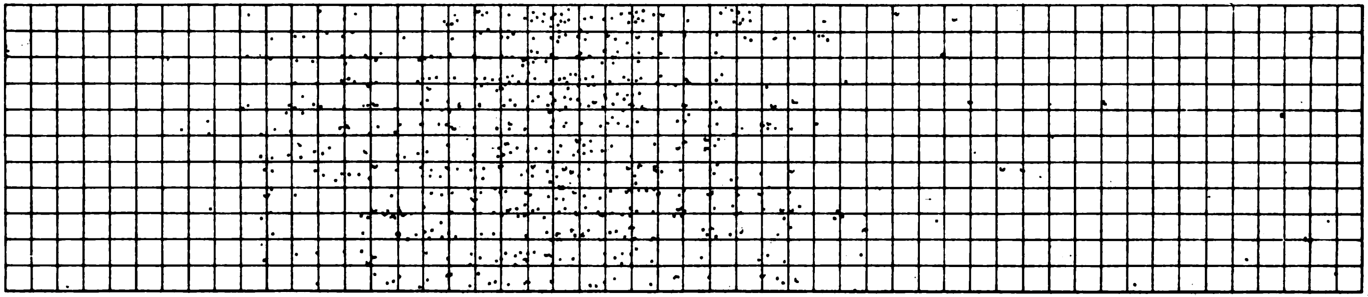
TARGET 52 × 11 FT. MADE OF 1 INCH SPRUCE BOARDS.

TARGET RECORD OF LOWELL BATTERY GUN CAL. .45

AT SANDY HOOK N.J. —— APRIL 18th 1878.

TARGET 1000 YARDS FROM GUN.

Nº OF ROUNDS FIRED 983. Nº NOT THROUGH 87 Nº OF DIRECT HITS 518



TARGET 52 × 11 FT. MADE OF 1 INCH SPRUCE BOARDS.

Direct Hits are represented thus . . . .·

Hits not through are represented thus. . ^

Accompanying Appendix 8, 1878

APPENDIX S 1.

TRIAL OF THE TAYLOR BATTERY GUN, CALIBER .43, MAY 6, 1878.

(Seven plates.)

DESCRIPTION OF THE TAYLOR BATTERY GUN, CALIBER 0″.43 (FURNISHED BY THE INVENTOR).

This gun is an invention of James P. Taylor, of Tennessee.

Plate I, Fig. I, of the accompanying drawings is a perspective view of the gun upon its carriage.

Plate II, Fig. II, represents a vertical longitudinal section through the breech of the same in a central plane.

Plate III, Fig. III, represents a vertical transverse section on the line 3-3, Fig. II, looking rearward.

Fig. IV is a plan view of a portion of the same.

Fig. V is an elevation of a cartridge-case or package as shipped.

Fig. VI is an elevation of the same as opened and passed to the gun.

Fig. VII is a plan of the same empty.

The Taylor machine gun, as shown in the drawings above referred to, has in the gun proper a horizontal range of parallel rifle barrels, B, five in number, of 0″.43 caliber, securely united to each other and to a hollow breech, C, which contains the firing mechanism, &c., and supports upon its top the cartridge hopper H. A hand-crank, *c f* (Fig. I), at the right-hand side of breech, operates a transverse shaft, S, common to the firing mechanism, &c., of all the barrels.

The gun has been mounted upon a thoroughly furnished field carriage, as shown in Fig. I, by means of a pair of trunnions, *t*, attached to forward extension of the sides of the breech and journaled in a swiveled saddle, *s s*, immediately over the carriage axle and by a vertical elevating screw, *e s*, raised and lowered by a swiveled hand nut, *h n*.

Between the elevating screw *e s* and the breech a device for spreading the fire is interposed. This device consists of a hollow, laterally extended head, *h*, swiveled to the screw *e s*; a slide, *s h*, working in this head and attached by ball and sockets, *b s*, to the bottom of the breech; a hand lever, *l s*, extending rearwardly through said slide from a fulcrum on said head; and a pair of stop-jaws within said head adjusted to any desired distance apart by means of a right and left screw-shaft operated by a hand wheel, *h w*, at its left-hand end. A folding seat, *f s*, upon the trail of the carriage accommodates a man in convenient position to manipulate the spreading lever *l s* by means of his left hand, while with his right he turns the firing-crank *c f*. A folding breech-sight, s^1, and a rigid front sight, s^2, are attached respectively to the top of the breech and to the top of the barrel frame F in line with the right-hand barrel. Other appurtenances of the gun seen in Fig. I and not in the other figures require no particular description.

The features of peculiarity in the gun, apart from details of mechanical workmanship, are comprised in the parts within and upon the breech. These are shown on a larger scale in Figs. II, III, and IV; and the peculiar mode of packing the cartridges, which is an auxiliary feature, is illustrated on a like scale in Figs. V, VI, and VII (Plate III).

The gun is designed for center-primed fixed ammunition of a standard rifle range; and packed as aforesaid, the same is designed and adapted to be distributed indiscriminately to infantry and the machine-gun batteries. Each case or package contains twenty-five cartridges in five rows of five each, with their heads abutting against each other at a certain distance from the top of the lower part of the case, as illustrated by Fig. VI. The ball ends are kept at the proper distance apart, and in proper position, as illustrated in Fig. VII, by means of crossed strips of straw-board within the case, which is of the same material.

The ammunition is passed to the gun as illustrated in Fig. VI; the heads of the cartridges being first pressed for an instant against a gauge-plate, *g p*, which is elevated while in use, as shown in Fig. I. The case is now lowered, with the top row of cartridges in horizontal or nearly horizontal positions, and the heads of all the cartridges are thus instantly arranged with the utmost facility behind six guide fingers, *g f*, which, with a fixed gauge-plate, $g\ p^2$, behind the same, projects upward from the top of the hopper H. The cartridge-case is immediately withdrawn, leaving the cartridges equally distributed between the fingers, which conduct the same downward and laterally to five feed-ports, behind and in line with the respective barrels. Owing to the mode of packing the cartridges in equal rows, it makes no difference which side of the case the fingers enter. A gauge-slide, carrying spring-tongues which project into the said feed-ports, regulates the length of the latter for ball cartridges and blanks or for cartridges of different lengths, and supports the front ends of the same. Another set of spring-tongues are attached within the rear ends of the feed-ports. The throats or interspaces between the fingers *f g*, except the middle space, diverge, in order to distribute their contents, as shown in Fig. III, and all the hopper attachments above described are supported by a cam-plate, which is hinged at its front edge, so as to turn forward over the barrels to expose the parts beneath. The lower part of the hopper is also attached to the breech by parallel swinging links for the same purpose.

Beneath the cam-plate of the hopper H the cartridges are received by "valves," *h v*, which are beneath and in line with the respective feed-ports when the hopper is closed for firing, as represented. Each of these valves is composed of two pivoted parts, pressed into a certain position by springs, and adapted to assume a certain second position. In the latter position of said parts, the valve receives a cartridge into a trough formed by the two parts. In the first position of said parts, the cartridge is dropped into the breech-chamber behind the bore of the barrel. Both positions are illustrated in Fig. III.

Longitudinal partitions, P, and wall plates, P^2, in the breech form the breech-chambers behind the respective barrels, and form guides, &c., for a series of sliding "locks," L, and their appurtenances, by which the said hopper-valves are operated as aforesaid and all the subsequent operations are performed; said locks, &c., being actuated by a series of cams, A, on the shaft S. Said operations of the hopper-valves is accomplished by an incline at the forward end of each lock-plunger at top (see Fig. II) and a corresponding incline on the rear end of each part of each hopper-valve at bottom.

When the lock in the corresponding breech-chamber is retracted, the released parts of the valve assume their first or normal position, and the cartridge is dropped.

Within the said breech-chamber the cartridge is arrested by a sectional floor, *f*, of trough shape, the parts of which, like those of each hopper-valve, have two positions, both illustrated in Fig. III. In the first or

normal position of said parts of said floor, they receive the dropped cartridge as aforesaid, and support the ball end of the same in line with the bore of the corresponding barrel. The lock L now advances and drives the cartridge partially into said bore; and then, after opening the floor *f*, so as to clear the flange of the shell, completes the operation of driving the cartridge home. In this operation, a pair of driving shoulders, *d s*, (Fig. II.) on the corresponding cam A, engaging with matching shoulders within the bifurcated yoke or carrier of the lock, carry the latter forward, and lateral bevels at the front end of the lock-plunger, engaging with cam arms, *c a*, (Fig. III) to which the respective parts of said floor, *f*, are attached, open said floor at the proper moment, as above described. It is closed by springs of which said cam-arms are extensions.

A pair of guide-springs, *g s*, immediately above each floor, *f*, support each cartridge laterally in line with the corresponding bore, and are pressed into recesses in the walls of the breech-chamber by the advancing front end of the lock.

Each cartridge is tightly clamped in the barrel, preliminary to firing and during this operation, by means of the corresponding lock, which is held for said purpose in its most advanced position by means of a concentric peripheral surface, on its cam A, engaging with matching surfaces within the yoke of the lock. The position of all the parts in one breech-chamber immediately before firing is illustrated in Fig. II, at the plane of section.

An axial firing-pin, *f p*, projected by a coiled spring, *s f*, is provided in each lock. One is shown in cocked position in Fig. II. Said pin has a head at its rear end to which a cocking slide in the form of a detent-hook, *d h*, is attached by a loose knuckle joint, and the head of said hook engages with a detent-shoulder, *s d*, at the top and rear end of the groove in which said hook slides. Said hook is made to so engage by means of a projection or rib, *r*, on the snatching side of the corresponding cam A. The outer end of this rib just comes in contact with an inward projection, *p*, on the head of the detent-hook, and being suitably beveled, presses said hook outward until said projection clears said rib. The hook is subsequently drawn inward by the lateral wall of its guide-groove, and said projection is thus brought behind said rib, *r*. As the driving shoulders *d s* continue to act, said rib supports said detent-hook, *d h*, by means of said projection, *p*, until the head of the hook engages with said detent-shoulder, *s d*. Said rib then passes out of contact with said projection, but the detent-hook remains engaged with the detent-shoulder, and during the remainder of the forward movement of the lock the firing-pin is cocked by being kept stationary with its detent-hook, while the remainder of the lock advances. The position of the parts at this stage is illustrated as aforesaid by Fig. II. At the proper moment, a tripping projection on the cam, comes in contact with said projection, *p*, on the detent-hook, and disengages the latter from the detent-shoulder, *s d*. The firing-pin is then instantly projected by its spring, *s f*, and the cartridge is exploded.

For retracting the empty shells from the respective barrels, a pair of sliding retractors are attached to the sides of each lock at its forward end. The front ends of these retractors are the customary beveled hooks, and are adapted to spring apart as they are forced past the rim of the shell into recesses provided for their reception in the breech of each barrel. The retraction of each lock is accomplished by the same driving shoulders, *d s*, of its cam, A, engaging with matching shoulders at the rear edge of the lock-yoke at bottom. During the movement thus im-

parted, the shell-retractors remain stationary until the point of the firing-pin is clear of the shell, and then, by their guide lugs and screws reaching the front ends of the slots which provide said dwell, the retractors travel with the remainder of the lock and draw the shell out beyond the floor *f*, where an ample opening, *o*, at bottom provides for its escape.

The gravity of the shell is not, however, depended on, but at the proper moment an ejector, pivoted in the top of each lock, strikes each shell, and drives it forcibly out of the grasp of the retractor through the said opening *o* beneath, from which it falls clear of the gun. Each ejector is operated by bevel inclined and sunken surfaces formed on the tops of the partitions and wall-plates of the breech through the medium of laterally projecting pins, p^1 p^2, with which the ejector is provided on the respective sides of its pivot.

Immediately after the ejection of a shell from a given chamber, the lock of said chamber releases the corresponding hopper-valve, and another cartridge is deposited in front of the lock upon the floor of said chamber in readiness for the repetition of the loading, firing, and shell-ejecting operations above described.

The cams A are so arranged as to operate the locks L in succession. The firing is consequently continuous, while the hopper-chambers are all fed simultaneously.

Beginning with the lock at the left hand side of the gun in the position in which it is shown in Fig. IV, and with the top of the breech fully opened, as illustrated, the detent-hook of this lock can be sprung out and removed; and after the dismantled lock is driven forward until a guide-lug at its front end appears in a notch, *z*, the lock can be lifted bodily out of the breech. Access can then be had to the detent-hook of the next lock, and in like manner all the locks can thus be removed in succession.

The hand-crank *c f* of the shaft S is attached by a spring-catch, *y*, so as to render it quickly removable at will to render the gun inoperative temporarily; and the bearings of said shaft have caps, *x*, attached by screws, so as to render the shaft with its cams removable after the locks are taken out.

The partitions P of the breech can now be lifted out, being simply held in place by dovetailed sockets, *w*, at both ends of each, as shown in Fig. IV, and the wall-plates P^2 P^2, which form the outer guides, &c., can be removed, being attached by four screws in each side of the breech.

The gun can thus be very quickly dismantled, or access can be had to any of its working parts at will; and if either lock should become disabled, it could be quickly removed and the others would then be effective.

The gun is adapted to be made with any desired number of barrels without change of plan, and the parts belonging to the respective barrels may be interchangeable, so as to be substituted for each other or replaced from the manufactory with the utmost facility.

Other general advantages *claimed* for the gun are:

(1.) Economy, great certainty and rapidity in loading, owing to the transfer of the ammunition directly to the gun from simple paper boxes, n which the same is packed for transportation at the cartridge factory.

(2.) Simplicity and compactness, with certainty in the firing and shell-ejecting mechanism.

(3.) Effective support against recoil in line with the respective barrels as afforded by the operating cams.

(4.) Convenience of access to the working parts of the gun without dismantling the same.

(5.) Simplicity and convenience of means for manipulating the gun in action.

Special features of present gun:

(1.) The combination of the breech-block, the series of barrels arranged in a horizontal plane, the sliding locks or plungers, and the cams or eccentrics carried by a shaft transverse to the barrels, and actuating the locks or plungers in succession.

(2.) The cams constructed with concentric front and rear portions to cause a dwell of the plunger at each extremity of its stroke.

(3.) The breech-frame constructed with removable longitudinal bars.

(4.) A feed-plate constructed with flanged grooves or guides adapted to receive and draw the cartridges from the cases in which they are packed and convey them to a feed opening or openings of suitable character.

(5.) A hopper or feeder constructed with flanges or grooves for the reception of the cartridges and divergent throats to conduct them to the breech-chamber.

(6.) A feeder for machine-guns, consisting of a series of parallel bars, with spaces for the automatic arranging or assembling of the cartridges with their points in corresponding position preliminary to their introduction into the breech or charge-chamber.

(7.) The blades or fingers for drawing cartridges by their flanges from cases in which they are packed.

(8.) The combination of a series of cams carried by a through shaft, and a series of followers bifurcated to pass the said shaft when operated by the cams.

(9.) The cams with their shoulders in combination with the lock-carriers or yokes and their shoulders acted on by the said cams.

(10.) The sliding lock-carriers or yokes, each having a bifurcation to adapt it to pass the shaft, and a vertical slot for the passage of the operating cam.

(11.) The combination of the operating cams, the lock-carriers (or yokes) and the sliding locks or plungers constructed, connected, and operated as shown.

(12.) The feeding-hopper provided with the oscillating valves in combination with the sliding locks or followers and their top-plates for operating the said valves.

(13.) The combination of the firing-pins and the removable cocking-slides.

(14.) The spring guiding-jaws in combination with the firing-chambers and extractors, and the ejectors for knocking the shells out from between said jaws.

(15.) The plate or blade projecting down within each hopper-throat to serve as a guide for the points of the cartridges, and adjustable by means of a set-screw to suit cartridges of different lengths.

(16.) The combination with the guide-plates or fingers and the fixed back plate of the extension gauge-plate to serve as a guide in introducing the cartridges.

PROPOSED MODIFICATIONS.

Fig. VIII, Plate IV, accompanying, represents a vertical longitudinal section of the breech of an improved gun, which was illustrated by a wooden model at the test of the gun above described.

Fig. IX, Plate V, represents a vertical transverse section of the same on the line 3–3, Fig. VIII.

Fig. X, Plate V, is a plan of one of the breech-chambers and the parts therein.

Fig. XI, Plate IV, is a perspective view of portions of one of the improved shell-extractors and their appurtenances.

Fig. XII, Plate IV, is a top view of the same parts.

Figs. VIII and X: 1 1 1 represents the barrels; 2, the breech-block; 3, the breech-frame; 4, the breech-cover; 5 5, hopper fingers; 6, fixed gauge-plate behind fingers 5; 7, extension gauge-plates; 7ª, set-screws for holding the latter; 8, the actuating-cams; 9, their shaft; 10, the sliding locks or followers; 11, the driving-crank; 12, shoulders or flanges on cams 8; 13, 14, lugs or flanges engaged by 12; 15, the bifurcated lock-carriers or yokes which are provided with 13, 14.

Each sliding lock or follower carries a firing-pin, 17, attached to a slide, 18, which works within the lock-carrier 15, and is formed with a laterally-projecting lug, 19, with which engages a latch, 20, pivoted at its lower end and made sufficiently elastic to admit of it being deflected laterally to release the lug 19. 16 is a rod sliding within the lock-carrier, and grooved longitudinally on one side so as to work over a guiding-pin, which limits its forward movement. 21 is a vertically sliding stop held in position, as illustrated in Fig. VIII, by a spring-catch, 21ª, and serving to receive the impact of the forward end of the sliding-rod 16 at each forward stroke of the lock-carrier, so as to press back the latch 20, carrying with it the firing-pin 17, in readiness for the firing action, which is effected by the contact of the side of the revolving cam with a projecting end of the latch 20, throwing the latter off from the lug 19, and thus releasing the firing-pin. 22 is the spring by which the firing-pin is driven forward when released.

By retracting the spring-catch 21ª the stop 21 may be drawn down as illustrated in dotted lines in Figs. VIII and IX, so that it will offer no resistance to the sliding-rod 16 when it is desired to suspend the operation of the firing mechanism. At each backward stroke of the lock-carrier the lug 19 of the firing-pin slips past the laterally-sliding latch 20, so as to be caught thereby, the backward movement of the latch being stopped at this point by contact with the shaft 9.

The cartridge-extractor consists of a pair of jaws, 23 (Figs. IX and X), fitted on each side of the sliding-lock or followers, and having limited longitudinal play thereon. These jaws slip over the flange of the cartridge when the sliding-lock or follower comes in contact therewith, and pass with it into the breech-chamber, passing between a pair of cheek-plates, 24, which are carried by a rod, 25, attached to a yoke, 26, actuated by a cam, 27, on the driving-shaft 9, in such a manner that when the jaws 23 are required to hold the cartridge flange firmly for the purpose of withdrawing it from the gun, the cheek-plates 24 will advance on both sides of the jaws so as to hold them firmly to their work. In Fig. XII the cartridge extractors are shown in an intermediate position, which they reach shortly after the commencement of their forward motion. They then pass forward between the cheek-plates and around the flange, after which the cheek-plates are moved forward to the oblique shoulders, where they are firmly held, so that when the jaws are retracted they are pressed tightly between the plates, thus effectually preventing the escape of the cartridge shell from the jaws. The cheek-plates afterward receive a backward motion, so that the spring-jaws may be free to pass over the flange at their next forward movement. The

forward position of the parts which they occupy in retracting the shell, in readiness for its ejection, is represented in Fig. XI.

28, 28, represent the hopper-valves, and 29 their springs.

Each of the ejectors, by which the shells are expelled from the gun after they are extracted by the retracting followers, consists of a lever of peculiar shape constructed with a long horizontal arm, 30 (Fig. XIII, Plate V), and a short vertical arm, 31, the latter of which projects into a groove in the top of a sliding follower, and receives the impact of a pin or tappet, 35, just before the follower reaches the rear termination of its stroke so as to impart a sudden downward movement to the horizontal arm 30 and strike the shell with a sharp blow, throwing it quickly from the gun. This effect is assisted by the spring guides 32, 32, between which the cartridge shell rests, and which are pressed together by their elasticity, affording sufficient resistance to the ejection of the cartridge to cause it to be thrown out with a more rapid motion. The spring guides 32 also serve to center the cartridge in the loading chamber in line with the axis of the firing-chamber, in readiness to be inserted therein, and secure it against slipping and falling out when the gun is elevated. They serve also as guides for the extractors and the cheek-plates which hold the same.

33 represents the adjusting-plate of the hopper, and 34 its clamp-screw.

The operation of the parts is graphically illustrated in Figs. VIII and IX, and requires no further description.

Fig. IX also illustrates another proposed change, to wit, the making of the divergent passages which lead from the feeding fingers curved instead of angular and of greater height, so as to more fully insure the free movement of the cartridges in the outer passages.

Fig. X illustrates still another change, which consists in making each lock-carrier or yoke single and of one piece, instead of double and of two pieces, as heretofore.

The additional claims as to originality allowed on the above improvements are as follows:

(1.) The lock-carriers or followers 10, constructed as herein shown and described, and carrying the firing-pins, and the devices for retracting and releasing the same, as explained.

(2.) The combination of spring firing-pin, the latch, the sliding rod, and the stop, with the cam adapted to retract said latch and cause the discharge of the piece, as explained.

(3.) The combination with the firing-pin, sliding-rod, and latch, of a retractable stop to prevent the operation of the firing-mechanism when desired.

(4.) A machine-gun, provided with cartridge extractors, 23, and a locking device, 24, moved relatively to the said extractors by an independent connection with the main shaft, substantially as set forth.

RESULTS OF FIRING AT SANDY HOOK, NEW YORK HARBOR.

(See Appendix A, and Plates VI and VII.)

On the 16th of May the gun was fired for initial velocity, using folded head cartridges, an average of 10 rounds giving a velocity of 1,297 feet per second. The gun was then fired to test its mechanism, 1,000 rounds each of folded and solid head cartridges being used. During the firing of the first series the gun was clogged four times, caused by cartridges not dropping into proper position to be forced into the chamber, and

during the second series the gun was clogged six times, due to the same cause, one of the six cartridges jamming in the chamber.

The next firings were for rapidity, using 850 solid and 1,077 folded head cartridges, or 1,927 in all; the greatest number fired in any single minute being 439. During the firings for rapidity four delays occurred, due to the cartridges not dropping from feeder into a proper position to be forced into the chamber; throughout all the firings these delays occurred, generally, if not invariably, at the end feeders.

One thousand rounds were next fired at a target 52′ by 11′, 1′ spruce boards, distant 200 yards from the gun; all hit. The gun was traversed about one-half its limit. Two delays during firing, due to clogging of cartridges. (See Plate VI.)

One thousand rounds were also fired at a similar target, distant 500 yards; total number of hits 776, the gun traversing about one-third its limit. (See Plate VII.)

In all the delays, with one exception, it was necessary to lift the plate holding the feed in order to get at the cartridges causing the trouble.

OPINION OF THE BOARD.

The Taylor battery-gun is an ingenious and promising machine-gun, but with the present arrangement for feeding the cartridges it does not compete favorably with other better perfected machine-guns that have been offered for test before the Board. It is probable that a more perfect feed can be effected for the service of this gun by the inventor; until this is accomplished, however, the Board cannot recommend the procurement by the United States of any of these guns for service.

APPENDIX A.

Record of firing with Taylor battery-gun, caliber 0″.433, at Sandy Hook, New York Harbor May 16, 1878.

Number of rounds.	Time.	Ammunition.	Initial velocity.	Total time.	Time of delays.	Time, less delays.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	1878.		Feet.				
1	May 16	Remington folded head, cal. 0″.433.	1,268	....	....	....	Fired into sand butt for rapidity. Average, 1,297 feet.
1	May 16	....do	1,290	....	....	....	
1	May 16	....do	1,285	....	....	....	
1	May 16	....do	1,307	....	....	....	
1	May 16	....do	1,314	....	....	....	
1	May 16	....do	1,305	....	....	....	
1	May 16	....do	1,299	....	....	....	
1	May 16	....do	1,289	....	....	....	
1	May 16	....do	1,295	....	....	....	
1	May 16	....do	1,301	....	....	....	
1,000	May 16	....do	....	....	....	....	Fired into sand butt to try mechanism of gun. Gun caught four times, caused by cartridge not dropping into proper position to be forced into chamber. One misfire.
1,000	May 16	Remington solid head, cal. 0″.433.	....	....	....	....	Fired into sand butt to try mechanism of gun. Gun caught six times, caused by cartridge not dropping into proper position to be forced into chamber. One of these cartridges jammed in chamber.

Record of firing with Taylor-battery gun, &c.—Continued.

Number of rounds.	Time.	Ammunition.	Initial velocity.	Total time.	Time of delays.	Time, less delays.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
225	1878. May 16	Remington solid head, cal. 0''.433.	*Feet.*	1'	2'' 25'' 9'' } 36''	24''	Fired into sand butt for rapidity.	Two delays caused by cartridges not dropping into proper positions to be forced into chamber; the delay of two seconds caused by error in thinking cartridge had not fallen properly. In the last delay the nine seconds completed the minute, and the gun was not then in working order.
100	May 16	....do	......	18''	....	....		
275	May 16	....do	......	47''	....	....		Gun stopped at end of 47'', caused by cartridge not dropping into proper position to be forced into chamber.
250	May 16	....do	......	42''	....	....		
337	May 16	Remington folded head, cal. 0''.433.	......	1'	....	....		One misfire.
301	May 16	....do	......	1'	18''	42''		One delay, caused by cartridge not dropping into proper position to be forced into chamber.
439	May 16	....do	......	1'	....	....		
1,000	May 16	....do	......	4' 20''	50'' 23'' } 73''	3' 7''		Fired at 200-yard target for accuracy; 1,000 hits in target. Oscillator set at ½. Two delays, caused by cartridge not dropping into proper position to be forced into chamber.
1,000	May 16	....do	......	2' 29''	....	....		Fired at 500-yard target; 776 hits in target. Oscillator set at ½. One misfire; one fired to complete the thousand.

In all the delays, with the exception of the one of two seconds, in the series of 225, it was necessary to lift up the plate holding the feed for the purpose of taking out the cartridges causing the trouble. In the last 1,000 rounds fired it was found that, when the crank did not turn freely (which is attributed to cartridges not falling properly), by shaking the crank the cartridge would get into proper position; hence, the delays in this 1,000 were so short that the time was not taken.

TAYLOR BATTERY GUN CAL. 0.43.

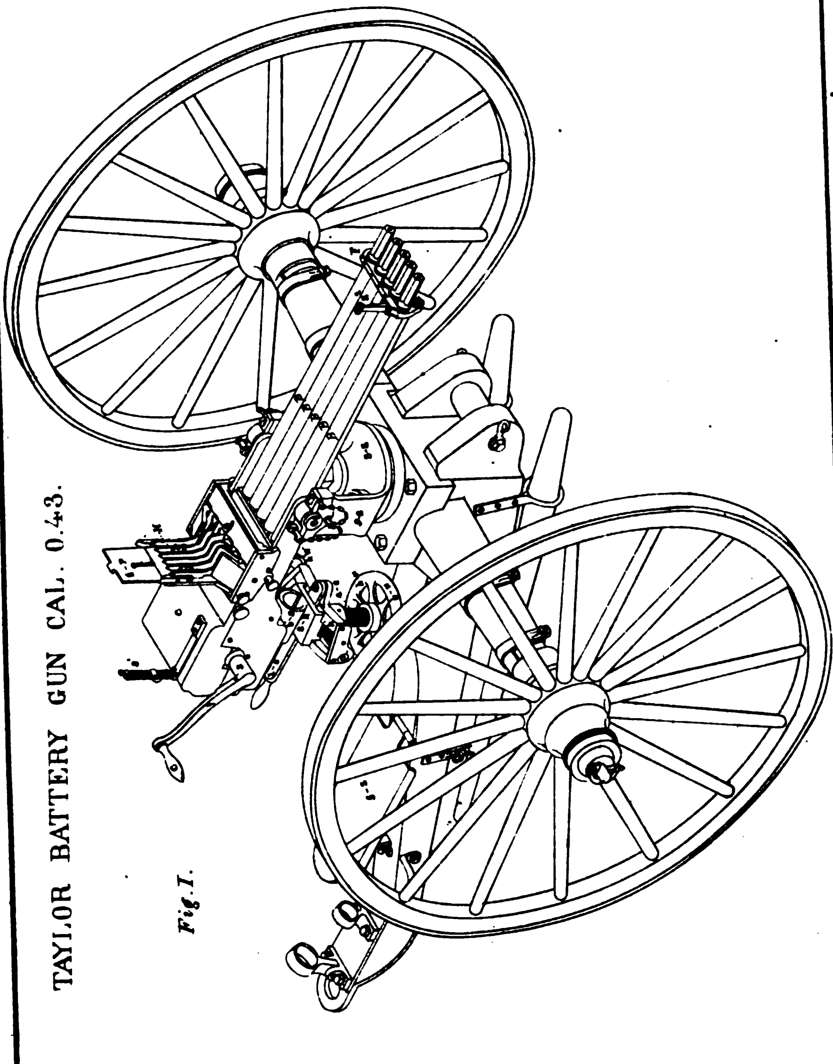


Fig. I.

PLATE II.

TAYLOR BATTERY GUN CAL. 0.43.

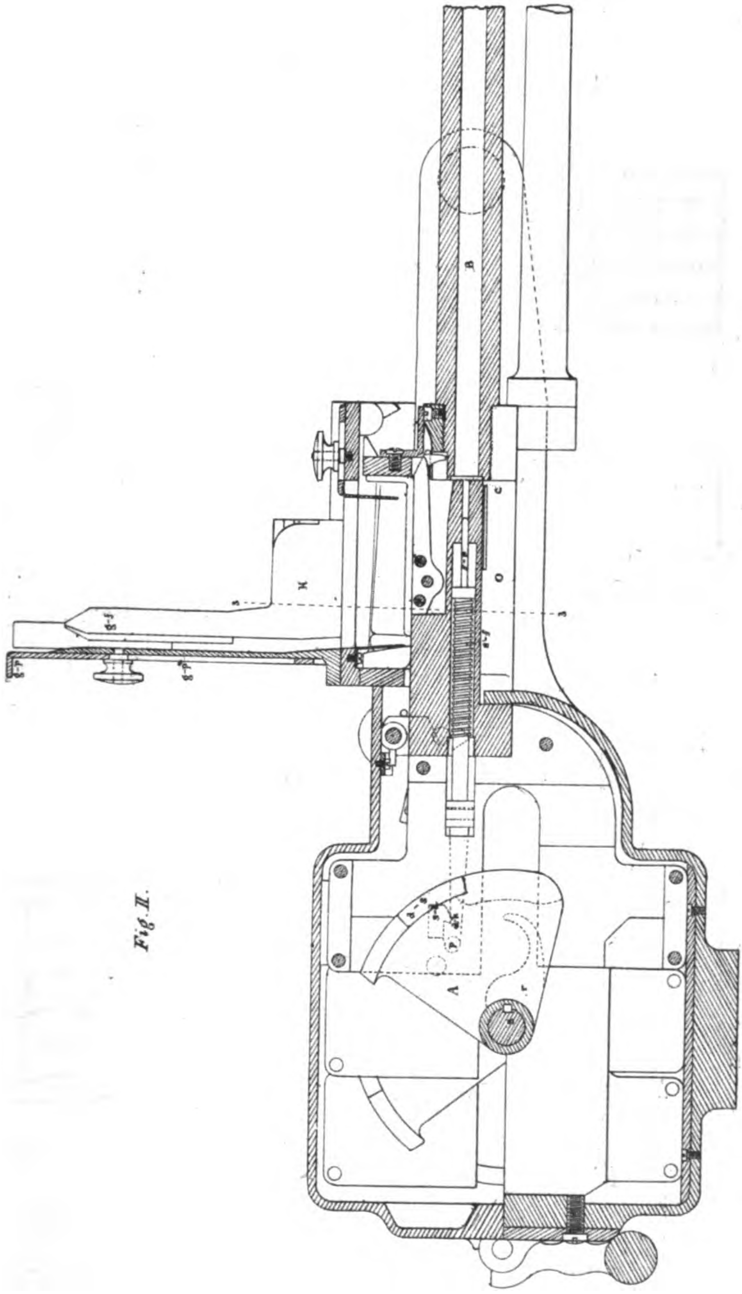
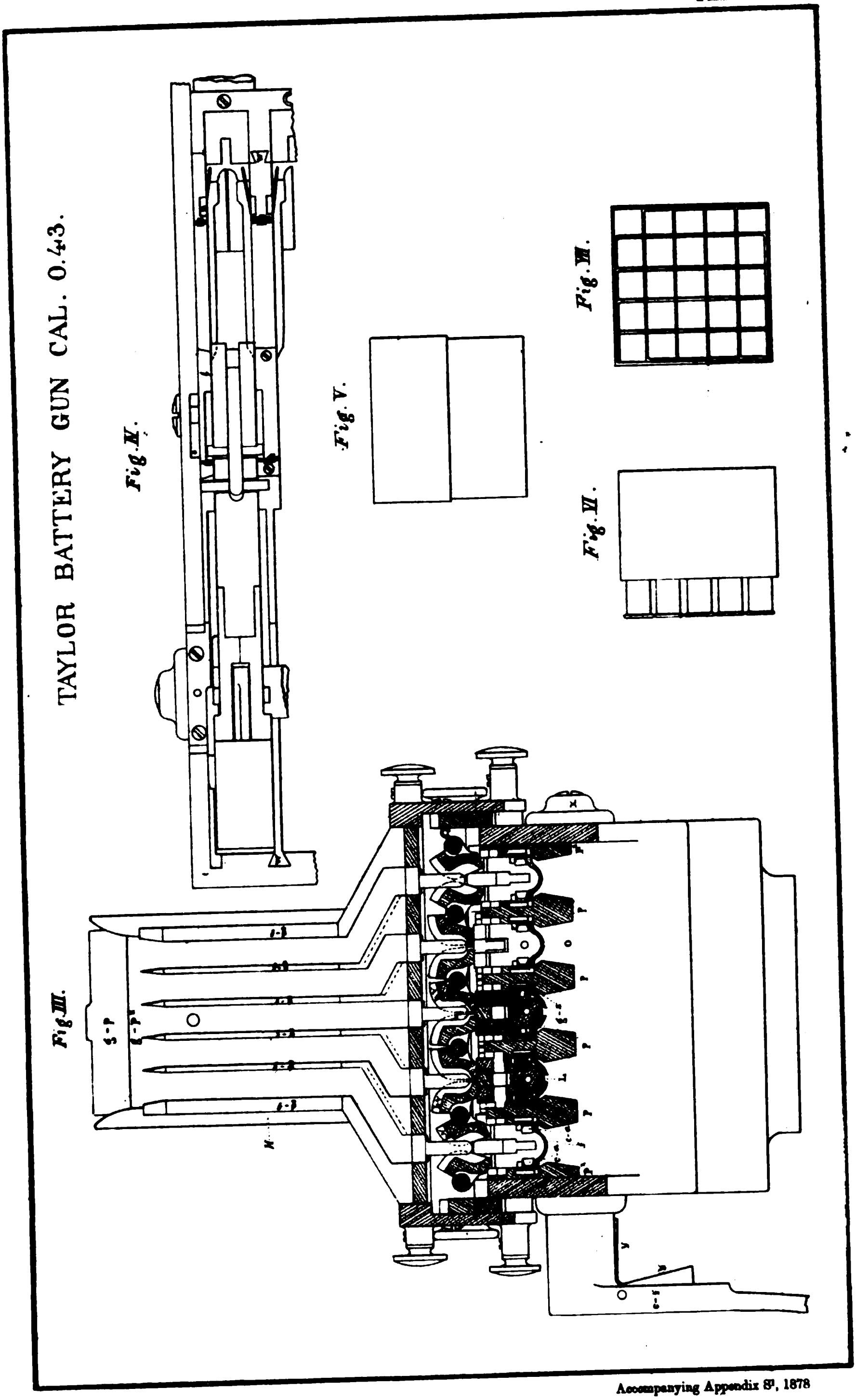


Fig. II.

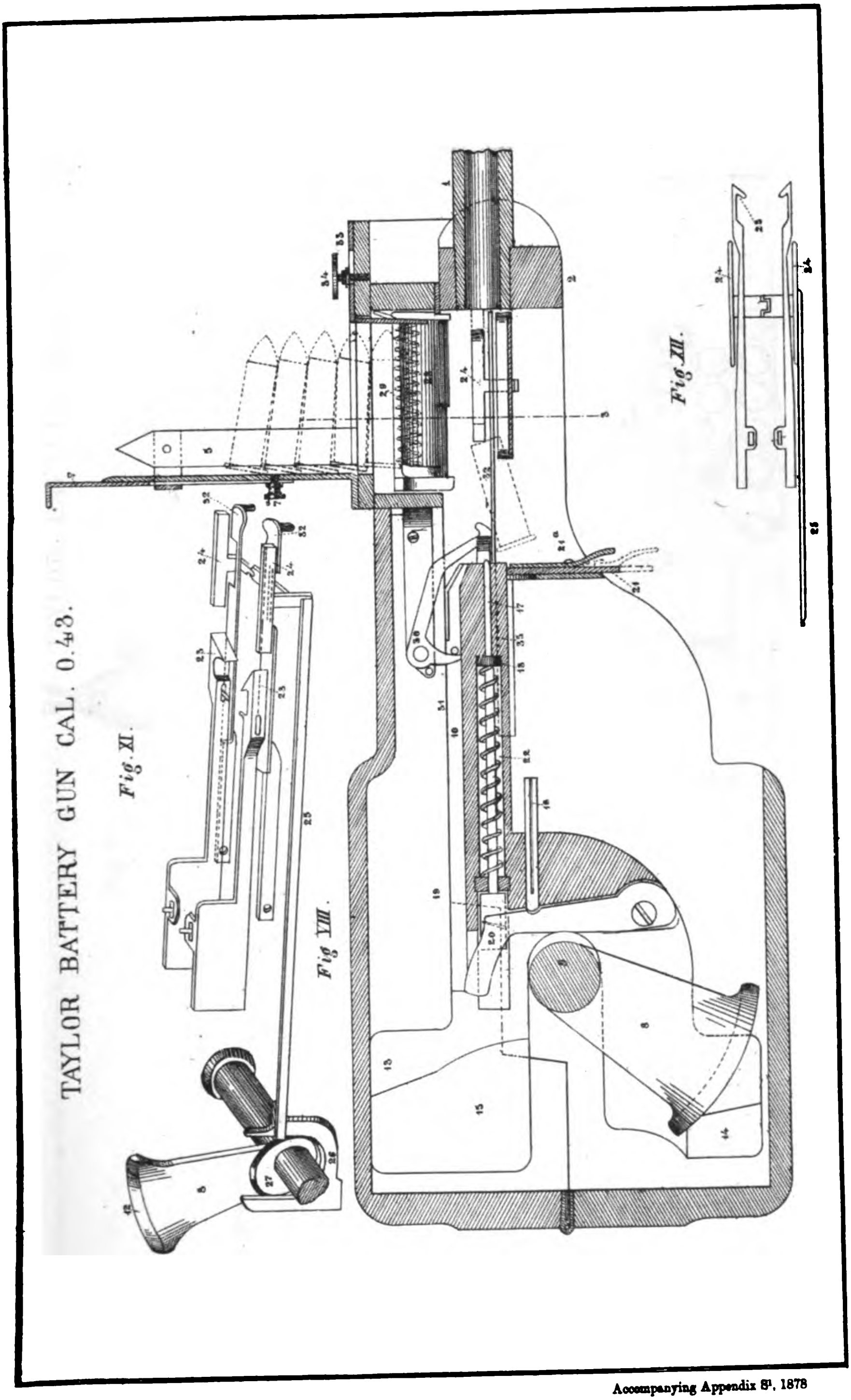
Accompanying Appendix S3, 1878.

PLATE III.



Accompanying Appendix S3, 1878

PLATE IV.



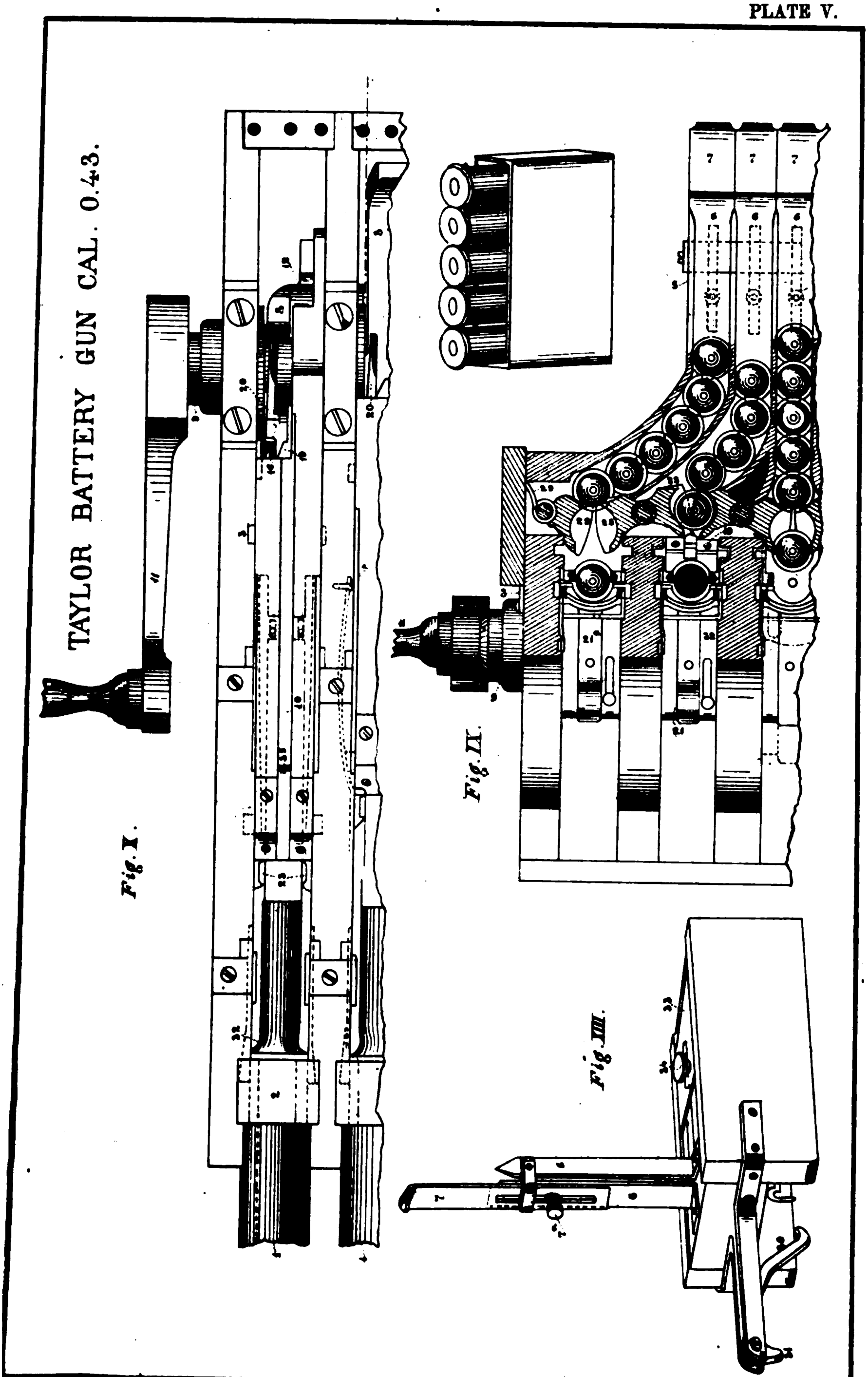
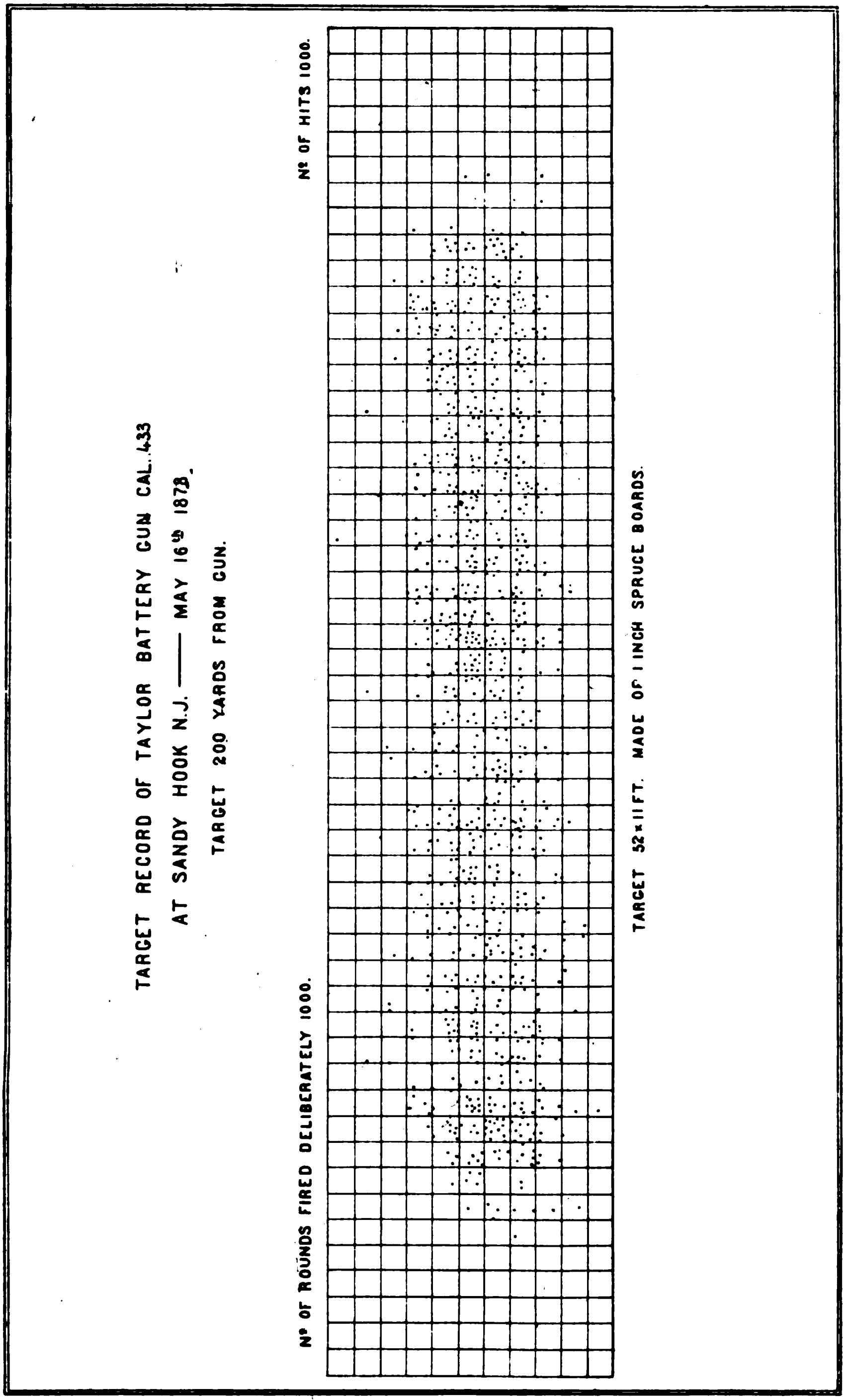

TAYLOR BATTERY GUN CAL. 0.43.
Fig. I.
Fig. II.
Fig. III.

PLATE VI.



Accompanying Appendix 6t. 1878

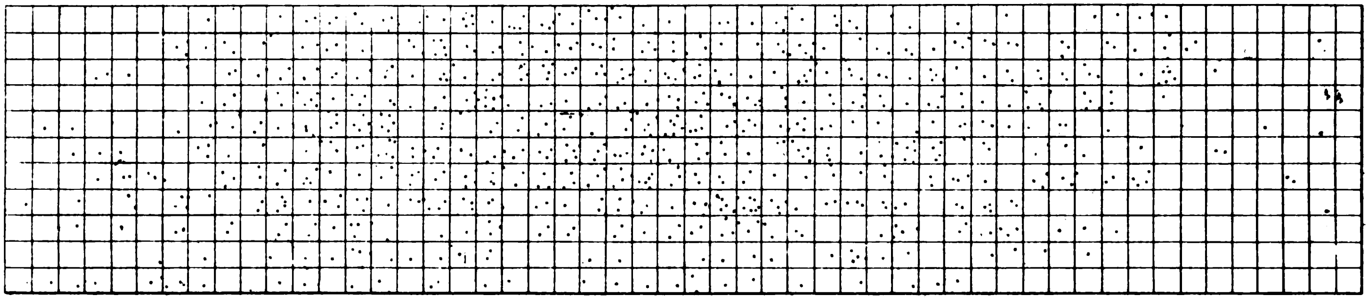
TARGET RECORD OF TAYLOR BATTERY GUN CAL. .433

AT SANDY HOOK N.J. —— MAY 16th 1878.

TARGET 500 YARDS FROM GUN.

No OF ROUNDS FIRED DELIBERATELY 1000

No OF HITS 778.



TARGET 52×11 FT. MADE OF 1 INCH SPRUCE BOARDS.

APPENDIX S 2.

TRIAL OF FUSES JULY, 1877, TO AUGUST, 1878.

(Twenty plates.)

DESCRIPTION OF FUSES, WITH PLATES AND RECORDS OF FIRING.

[NOTE.—At the request of Dr. Woodbridge, the description of this fuse has been left out. This will explain the absence of Plate XX.]

HOTCHKISS PERCUSSION FUSE.

(Plate I.)

Consists of a metal body, A, closed at the front end with a screw-cap, B; it has a conical hole at the rear, which is closed with a lead plug, C (the safety-plug), pressed in very tightly, so that the plug projects a little through the base of the body-case, toward the inside.

The plunger D is composed of lead cast into a brass casing to strengthen it, and to prevent the lead being upset by the shock of discharge. Two brass wires, F, cast into the lead on opposite sides of the plunger, hold it suspended in the case, the wires going through the holes in the bottom of the case, and being held securely in position by the safety-plug. The plunger has a nipple cast into the lead and is primed with an ordinary percussion cap; in its axis it has a powder-chamber, G, containing the igniting charge.

The operation of the fuse is thus: The safety-plug is dislodged backward into the interior of the projectile by the shock of discharge; the wires then being not held tight in the hole, the plunger is disengaged and rests on the bottom of the fuse-case, and is free to move in the line of axis. When the flight of the projectile is suddenly retarded by its striking any object, the plunger, in consequence of its inertia, is driven forward, and the primer strikes against the screw-cap, thus igniting the powder in the channel, and so firing the bursting charge of the projectile.

Record of firing with Hotchkiss percussion fuses, made at Sandy Hook, July 21, 1877, and August 31, 1877.

[Rifle used: 3″ wrought iron, No. 965. Powder: 1¼ pounds of old mortar. Shell: Dyer; weight, 8 pounds 15 ounces. Elevation: 1⅝°.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	Direct hit, 2′ above, 3′ right; exploded on striking ground behind target.
2	Nine paces in front of target; exploded on striking.
3	Direct hit, 3′ above, 8′ right; exploded on striking ground behind target.
4	Direct hit, 4′ above, 4½′ right; exploded on striking ground behind target.
5	Direct hit, 6′ above, 8′ right; exploded on striking ground behind target.
6	Over target, burst on striking ground.
7	Direct hit, ½′ above, 1′ left; burst on striking ground.
8	Over target, burst on striking ground.
9	Direct hit, 7′ above, 9′ right; burst in air after striking ground.
10	Direct hit, 5½′ above, 1½′ right; burst on striking ground.
11	Direct hit, 5′ above, 5′ right; did not explode.
12	Direct hit, 6′ above, 7′ right; did not explode.

Record of firing with Hotchkiss percussion fuses, &c.—Continued.

No. of round.	Remarks.
13	Direct hit, 4′ above, 3′ right; burst on striking ground.
14	Direct hit, 4′ below center; burst on striking ground.
15	Direct hit, 5¾′ below, ½′ right; burst on striking ground.
16	Over target; burst on striking ground.
17	Direct hit, 4′ above, 1½′ right; burst on striking ground.
18	Over target; burst on striking ground.
19	Direct hit, 5½′ below, 8′ right; burst on striking ground.
20	Over target; burst on striking ground.
21	Over target; burst on striking ground.
22	Over target; burst on striking ground.
23	Over target; did not explode.
24	Direct hit, 5′ below, ½′ right; burst on striking ground.
25	Direct hit, 2′ right of center; burst on striking ground.

THE SCHENKL PERCUSSION-FUSE.

(Plate II.)

Consists of a metal fuse-stock, A, inclosing a movable core-piece or steel plunger, B, bearing a musket-cap, C. The plunger, primed and capped, is held in place by a screw or pin, D, which passes through a hole in the side of the stock and plunger. A safety-cap, E, is screwed into the top of the fuse-stock, and its bottom is closed by a cork or leather stopper, F.

When the projectile is set in motion, the plunger, by its inertia, carries away the pin which confines it and presses against the bottom of the fuze-stock. When its motion is arrested, the inertia of the plunger causes the percussion-cap to impinge against the safety-cap, which ignites the priming, when the stopper in the bottom of the fuse-stock is blown out and the shell exploded.

As a precaution against danger while handling, the brass safety-cap is countersunk on one end and flat on the other. It is kept with the countersunk end down at all times except when loading; while this end is down, should the plunger become loose, the percussion-cap is prevented from coming in contact with the hard surface of the safety-cap, but on being turned end for end a plane surface is opposed to the percussion-cap, upon which it may strike. There is a slit cut in the top of the fuse-stock and cap, which is designed for the entrance of the fuse-wrench.

Record of firing with Schenkl percussion-fuses, made at Sandy Hook July 13, *and August* 31, 1877.

[Rifle used: 3″ wrought-iron rifle No. 965. Powder: 1¼ pounds of mortar. Shell: Dyer; weight, 8 pounds 15 ounces. Elevation: 1⅝°.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	Direct hit, 4′ below, 3′ right; did not explode.
2	Struck 50 paces in front; passed through target, but did not burst until striking about 200 yards beyond target.
3	Under target; exploded on striking.
4	Direct hit, 8′ right, 3′ above; did not explode.
5	Over target; exploded on striking.
6	Over target; exploded on striking ground second time.
7	Direct hit, 10′ right, 6½′ above; did not explode.

Record of firing with Schenkl percussion-fuses, &c.—Continued.

No. of round.	Remarks.
8	Direct hit, 2′ right, 4½″ above; burst on striking ground.
9	Struck 115 paces in front of target; burst on striking ground.
10	Over target; burst on striking ground third time.
11	Struck 40 paces in front of target; burst on striking ground.
12	Direct hit, 4′ below, 3′ left; burst going through target.
13	Direct hit, 5′ right of center; burst going through target.
14	Direct hit, 10′ right, 2′ below; burst on striking ground.
15	Direct hit, 7′ above center; burst on striking ground.
16	Direct hit, 5′ above, 2′ right; burst on striking ground.
17	Burst in air about 300 yards in front of target.
18	Over target; burst on striking ground.
19	Direct hit, 4′ above, 8′ left; burst on striking ground.
20	Direct hit, 2′ above, 5′ right; burst on striking ground.
21	Direct hit, 5′ above center; burst on striking ground.
22	Direct hit, 5′ below, 8′ left; burst on striking ground.
23	Direct hit, 6½′ below, 1′ right; burst on striking ground.
24	Over target; burst on striking ground.
25	Direct hit 3′ above, 1′ left; burst on striking ground.

THE ABSTERDAM PERCUSSION-FUSE.

(Plate III.)

Consists of a metal fuse-stock, A, closed at front end by a screw-cap, B; a movable plunger, C, cast around a cone-piece, D, and a hollow tin cylinder, E. The tin cylinder E at base of plunger is cut longitudinally, so that when opened out into recess F at base of fuse-stock the plunger is held in place securely until impact of the shell. The shock of discharge straightens out the tin, freeing the plunger which moves forward to cap B, exploding musket-cap on cone-piece which ignites bursting charge.

Record of firing with Absterdam percussion-fuses, made at Sandy Hook August 30, 1877.

[Rifle used: 4½″ siege-rifle No. 101. Powder: 3¼ pounds new mortar E. Z. Shell: Absterdam 24½ pounds. Elevation: 1° 50′.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	Over target; did not explode.
2	Direct hit, 7′ above, 3′ left; did not explode.
3	Direct hit, 4′ above center; did not explode.
4	Direct hit, 3½′ above center; burst going through target.
5	Over target; did not explode.
6	Direct hit, 1′ left, 1′ below; did not explode.
7	Direct hit, 3½′ left, 2½′ below; did not explode.
8	Direct hit, 2′ right, 1′ below; did not explode.
9	Direct hit, 3½′ left, 5½′ below; did not explode.
10	Direct hit, 4′ left, 1′ below; burst going through target.
11	Direct hit, 3½′ left, 1½′ above; burst on striking ground about 1,000 yards behind target.
12	Direct hit, 4½′ left, 1½′ above; burst on striking ground.
13	Direct hit, 4′ left, 3′ above; burst on striking ground.
14	Direct hit, 3′ left, ½′ above; did not explode.
15	Direct hit, 2′ left, ½′ above; did not explode.
16	Direct hit, 1′ left, 2′ above; burst on striking ground.
17	Direct hit, 3′ left, 7′ above; did not explode.
18	Direct hit, 4′ left, 4½′ above; did not explode.
19	Over target; did not explode.
20	Direct hit, 4½′ left, 4½′ above; did not explode.
21	Direct hit, 1′ left, 3½′ above; burst on striking ground.
22	Direct hit, 4′ left, 6½′ above; did not explode.
23	Direct hit, 1′ above center; did not explode.
24	Direct hit, 3′ left of center; exploded on striking ground.
25	Direct hit, 1′ left, 6′ above; did not explode.

EGGO PERCUSSION-FUSE.

(Plate IV.)

Consists of the stock A, upon the outer surface of the outer part of which is formed a screw-thread, to enable it to be screwed into the shell in the ordinary manner.

The outer end of the stock A is made close, with a flange to overlap the seam or joint, and with notches or holes to receive the wrench for screwing it in and out of the shell.

The inner end of the stock A is made open and is closed with a screw-plug, B, which is made with holes or notches to receive the wrench for screwing it in and out. C is the plunger, which is made hollow, and is provided with a nipple, D, at its outer end to receive a cap to cause the shell to be exploded when it strikes, by the forward movement of the plunger C, causing the cap to strike against the closed, outer end of the stock A.

The inner end of the stock A is notched or slotted transversely, to receive the ends of the hollow or tubular bar E, with the center of which is connected the inner end of the short tube F.

The ends of the bar E may be closed by a paper patch, a slight wooden plug, or other suitable means, to confine the powder until ignited.

The outer end of the tube F is flattened and contains a fulminate to be ignited by friction.

The device E F is connected with the plunger C by a wire G, one end of which is securely attached to the said plunger C, and its other end passes through the tube F.

The outer end of the wire G is flattened and roughed or barbed, so that when drawn through the tube F by the forward movement of the plunger C it may ignite the fulminate in the said tube F by friction, and thus explode the shell.

The screw-plug B has a hole through it to receive the tube F and protect it.

H is the safety-pin, which passes in through a screw-hole in the outer, closed end of the stock A in such a position that its forward end may rest against the end of the plunger C at the side of the cap-nipple, and thus holds the said plunger securely in place during transportation and handling, and absolutely secures the shell from being exploded by an accidental blow, jar, or fall.

The screw-pin H is removed when the shell is put into the gun to be fired.

Record of firing with Eggo percussion-fuses, made at Sandy Hook July 13 *and September* 6, 1877.

[Rifle used: 3″ wrought-iron rifle No. 965. Powder: $1\frac{1}{4}$ pounds of mortar. Shell: Dyer: weight, 8 pounds 15 ounces. Elevation: $1\frac{5}{8}°$.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	Struck 6 paces in front of target: exploded on striking and made 20 holes in target.
2	Struck 6 paces in front of target: exploded on striking and made 50 holes in target.
3	Direct hit, 4′ below, 3′ right: did not explode.
4	Struck 24 paces in front of target: exploded on striking.
5	Direct hit, 4′ below center; did not explode.
6	Over target: did not explode.
7	Right of target: did not explode.

Record of firing with Eggo percussion-fuse, &c.—Continued.

No. of round.	Remarks.
8	Direct hit, 3′ right, 2½′ below; burst on striking ground.
9	Struck 58 paces in front of target; did not burst.
10	Direct hit; keyholed 9′ right, 2′ above; did not burst. Sabot stripped in flight.
11	Struck 32 paces in front of target; did not burst.
12	Direct hit, 5′ below, 5′ right; burst.
13	Right of target; burst on striking ground.
14	Struck 2 paces in front of target; did not burst.
15	Right of target; did not burst.
16	Over target; did not burst.
17	Direct hit; keyholed 5′ below, 3′ right; did not burst. Sabot stripped in flight.
18	Struck 20 paces in front of target and burst.
19	Struck 76 paces in front of target; did not burst.
20	Struck 23 paces in front of target; did not burst.
21	Direct hit; keyholed 9′ right, 1½′ above; burst on striking ground 2d time. Sabot stripped in flight.
22	Struck 50 paces in front of target; did not burst.
23	Direct hit, 6″ above, 6′ right; burst on striking ground.
24	Struck 8 paces in front of target; burst on striking ground.

GERMAN PERCUSSION FUSE.

(Plate V.)

In this fuse a metal plunger, A, having a central fire-hole, B, is let into the fuse-hole and rests against the shoulders DD. Let into the top of the plunger and across its center is a metal bar, P, having a projecting point on its top side, the point being in center of fire-hole.

The plunger is retained in its place by a pin, C, which passes transversely into the fuse-hole, the side of which is put in contact with the point of the cap.

The outer end of the pin projects on the side of the shell, the projection being limited by the line of the cylindrical portion. The fuse-hole is closed by a screw-cap, F, having a small central screw-hole into which the fulminate-cap, G, is screwed.

When fired from a rifle-piece, the centrifugal force generated by the revolution of the shell throws out the pin C; the plunger by its inertia is retained at the bottom of the chamber during the flight of the projectile; at the moment of impact the projecting point on the plunger impinges against the fulminate, which, exploding, ignites the charge in the shell.

The fulminate-cap G and pin C are not applied to the shell until the instant of loading, when the loader, who carries these articles in a pouch, screws in a fulminate-cap and inserts the pin, previously feeling that the plunger does not stick.

To keep the bursting charge in place in the shell, a brass thimble, H, with a flange about the top, and small holes in the bottom, is first pressed into the fuse-hole and takes against the shoulder D. A piece of cloth is pasted over the fire-holes in the bottom of the thimble. In this thimble the metal plunger rests.

Record of firing with German percussion fuses, made at Sandy Hook August 31, 1878.

[Rifle used: 3″.15 (8 c. m.) Bochum breech-loading rifle No. 1. Powder: 1 pound 2 ounces of Krupp's mortar. Shell: Krupp; weight, 9 pounds 4 ounces. Elevation: 1° 50′.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	Direct hit, 2′ above center; burst going through target.
2	Burst in air near gun.
3	Over target; burst on striking ground.
4	Direct hit, 3½′ above, 2½′ right; burst going through target.
5	Direct hit, 2′ above center; burst going through target.
6	Over target; burst on striking ground.
7	Over target; burst on striking ground.
8	Direct hit, 1½′ below center; burst going through target.
9	Direct hit, 5½′ above, 1½′ left; burst going through target.
10	Direct hit, 6½′ above center; burst going through target.
11	Over target; burst on striking ground.
12	Direct hit, 3½′ above, 1′ left; burst going through target.
13	Direct hit, 6′ above, 1′ left; burst going through target.
14	Direct hit, 4′ below, 2′ right; burst going through target.
15	Direct hit, 2′ above, 3′ left; burst going through target.
16	Direct hit, ½′ right of center; burst going through target.
17	Direct hit, ½′ right of center; burst going through target.
18	Direct hit, 5½′ above, 1′ right; burst going through target.
19	Direct hit, 2′ above, 2′ right; burst going through target.
20	Direct hit, 2′ below, 2′ left; burst going through target.

ENGLISH PERCUSSION FUSES.

(Plate VI.)

PETTMAN FUSE.

(Fig. I.)

The Pettman fuse consists of the following parts: A, body; B, top-plug; C, plain ball; D, steady plug; E, detonating ball; F, cone plug; G, lead cup; H, suspending wire.

The steady and top plugs are cupped in the center to receive the small plain ball of brass wire which holds them apart; and to prevent the ball adhering from corrosion, the cups are slightly larger in diameter than the ball. Round the top of the steady plug runs a groove filled with detonating composition, and two fire-holes pass from the composition down through the plug.

The composition in the annular groove is covered with thin sheet-brass. The detonating ball, which is coated with composition, is covered with two hollow hemispheres of sheet-copper, and over these with silk. The cone plug (no longer coned) has three fire-holes and is supported by a copper wire which passes through the tube; but the hollow of the latter is enlarged below the wire to prevent its being choked. The lead cup (pure lead) does not rest on the bottom of the fuse, but is supported at the top on a shoulder on the cone plug.

Parts of fuse.	Copper.	Tin.	Zinc.
	Lbs. ozs.	*Lbs. ozs.*	*Lbs. ozs.*
Body and top plug	11 0	1 0	0 1½
Plain ball	70 0	....	30 0
Steady plug } Denotating ball and cone plug }	7 0	1 0	....

The detonating composition in the steady plug and on the detonating ball consists of—

	Parts.
Chlorate of potash	12
Sulphide of antimony	12
Sulphur	1
Mealed powder	1

On the discharge of the gun the suspending wire is broken and the lead cup crushed in consequence of the inertia of cone and steady plugs and of balls, which do not move instantaneously with the fuse and lead cup; sufficient space is therefore left for the disengagement of the balls, and on impact the fuse ignited by the concussion of the detonating ball on the inside of the body, or by the plain ball on the composition in the groove of the steady plug, which continuing to move, after the sudden check to the motion of the fuse, presses the plain ball between itself and the top plug.—(Owen's Modern Artillery.)

ROYAL LABORATORY FUSE.

(Fig. II.)

This fuse consists of the following parts: A, the brass stock or body; B, the brass screw-plug closing rear end of fuse; C, the lead plunger; D, the brass thimble; E, the brass safety-wire; and F, fulminate. The body has a solid head, having on the outside a square recess for fuse wrench, and on the inside a sharp pin projecting from the center. The screw-plug (B) has a hole through its center which is covered by a thin disk of brass secured on by solder; two small recesses in the bottom of the plug facilitate its insertion with a wrench. The lead plunger (C) has also a central hole through it, in the front end of which is placed the fulminate cap; the plunger has also two slight projections from its sides upon which rests the brass thimble D. Running through holes in the heads of fuse body and thimble, and to one side of center and resting on top of the plunger, is the twisted safety-wire E. In order to prevent the easy withdrawal of the safety-wire a small hole is bored into one side of fuse body and down to the hole through which the wire is inserted, and into this is poured melted lead. A strong cord facilitates the extraction of the wire before firing. Inserted in a loaded shell with the safety-wire removed, and meeting with a resisting object in flight, the plunger is thrown forward sheering off the shoulders; the fulminate striking the pin is ignited, the brass disk closing hole through screw plug is blown out, and the bursting-charge of shell ignited.

Record of firing with English percussion-fuses, made at Sandy Hook August 8 and 14, 1878

[Rifle used: 3″ wrought-iron rifle No. 965. Powder: 1¼ pounds of mortar. Shell: Dyer; weight, pounds 15 ounces. Elevation: 1⅝°.]

No. of round.	Remarks.
	Pettman percussion.
	Fired at 1,000-yard target:
1	Burst on striking ground.
2	Through target, struck ground beyond; did not burst.
3	Through target, struck ground beyond; did not burst.
4	Through target, struck ground beyond twice; did not burst.
5	Through target, struck ground beyond three times; did not burst.
6	Through target, two ricochets on ground; did not burst.
7	Through target, two ricochets on ground; did not burst.

Record of firing with English percussion-fuses, &c.—Continued.

No. of round.	Remarks
8	Through target; burst on striking ground beyond.
9	Over target; burst on striking ground beyond.
10	Over target, two ricochets on land, one on water; did not burst.
11	Through target, one ricochet on land and one on water; did not burst.
12	Through target, four ricochets on land; did not burst.
13	Through target; burst on striking ground beyond.
14	Struck 15 yards in front of target, ricochetted over and struck water once; did not burst.
15	Struck 40 yards in front of target, ricochetted over and struck water once; did not burst.
16	Through 1,000-yard target, ricochetted through mile target, struck ground beyond; did not burst.
17	Through 1,000-yard target, struck ground beyond, two ricochets on water; did not burst.
18	Over target; burst on striking ground beyond.
19	Through target, struck ground twice; did not burst.
20	Through target; burst on striking ground beyond;
21	Through target, struck ground twice, water once; did not burst.
22	Struck two feet in front of target and burst.
23	Through target, struck ground twice, water once; did not burst.
	General service R. L. percussion.
	Fired at 1,000-yard target:
1	Through target; burst on striking ground beyond; fuse-wire pulled out before firing.
2	Under target; burst on striking ground beyond; fuse-wire not pulled out.
3	Burst going through target; fuse-wire pulled out before firing.
4	Burst near muzzle; fuse-wire not pulled out.
5	Did not burst; time of flight 8¼ seconds.
6	Struck 10 feet in front of target and burst.
7	Burst going through target.
8	Struck 100 feet in front of target and burst.
9	Burst going through target.
10	Struck 15 feet in front of target and burst.
11	Through target; burst on striking ground beyond.
12	Through target; burst on striking ground beyond.
13	Burst going through target.
14	Burst going through target.
15	Burst going through target.
16	Burst in flight near 200-yard target.
17	Burst going through target.
18	Struck 75 yards in front of target and burst.
19	Struck 100 yards in front of target, ricochetted to mile target and burst; sabot stripped near 200 yard target.
20	Struck 10 feet in front of target and burst.
21	Struck 15 feet in front of target and burst.
22	Burst going through target.
23	Struck 30 feet in front of target and burst.

LISSBERGER FUSES.

Plate VII.

PERCUSSION-FUSE.

Fig. 1.

This fuse consists of a copper tapering body A, with enlarged head, but closed at the rear by a brass screw-plug B, which is hollow nearly its entire length. Fitting this screw-plug is the brass hollow cylinder C, filled with friction composition; the lower part of cylinder is closed, as shown in drawing. A wire, D, whose lower end is serrated and twisted, passes through central holes in the screw-plug B and the solid cylindrical plunger E; it has its upper end looped to form a shoulder against the plunger E. Between the plunger E and the end of screw-plug B is a disk of leather.

The lower end of screw-plug B is closed by a small quantity of rifle-powder and a disk of leather pressed in. The fuse body has about the

same taper rearward, and is inserted in shell the same as the ordinary paper time-fuse; when inserted in a shell whose flight is suddenly arrested, the serrated wire is drawn forward by the plunger, igniting the friction composition, and setting fire to powder charge.

TIME-FUSE.

Fig. II.

This is an ordinary paper fuse, A, which is ignited by means of an inertia igniter, B. The igniter B consists of four parts, the brass solid-headed shell *a*, slightly tapering on the exterior, having the holes in the head and side openings, as shown in drawing, for escape of gas; through the head of the body A is introduced the hollow brass cylinder *b*, whose lower end is cut and closed, as shown; within this cylinder is the lead plunger *c* and the friction-pellet *d*.

At the instant of discharge, the friction-pellet is forced back and through the rough-closed end of cylinder by the plunger and the time-fuse thus ignited.

Record of firing with Lissberger fuses (time and percussion), made at Sandy Hook, May 20, 1878.

[Rifle used: 3″ wrought-iron rifle No. 965. Powder: 1¼ pounds of old mortar. Shell: Dyer; weight, pounds 15 ounces. Elevation: 5°, ¾°, 1⅜°, and 1¼°.]

No. of round.	Remarks.
	Time, 5 seconds.
	Fired over water for time:
1	Burst in air; time 4¼ seconds.
2	Burst in air; time 4¼ seconds.
3	Burst in air; time 3½ seconds.
4	Burst in air; time 2¼ seconds.
	Percussion.
	Fired at 500-yard target:
1	Burst going through target.
2	Through target; burst on striking ground beyond.
3	Burst going through target.
4	Through target; burst on striking ground beyond.
5	Did not burst.
6	Did not burst.
7	Through target; burst on striking ground beyond.
8	Burst at muzzle.
	Fired at 1,000-yard target:
9	Burst at muzzle.
10	Through target; did not burst.
11	Did not burst.
12	Through target; did not burst.
13	Through target; burst on striking ground beyond.
14	Through target; did not burst.
15	Struck ground, ricochetted through target; did not burst.
16	Struck ground, ricochetted through target; did not burst.
	Fired down beach:
17	Burst at muzzle.
18	Did not burst.
19	Did not burst.
20	Did not burst.
21	Did not burst.
22	Did not burst.
23	Did not burst.

GERMAN TIME-FUSE.

(Plate VIII.)

Fig. 1 is a full-sized side view of fuse ready for insertion in the shell.

Fig. 2 is a plan of same.

Fig. 3 is a sectional view.

Figs. 4, 5, 6, 7, and 8 show in detail the different parts of the fuse.

The fuse consists of the *body*, or fuse proper, in two parts, A and B, and the igniter C.

The lower part B is of lead and tin, and is cast around the brass stem *a;* the upper part of this stem is provided on the inside and outside with screw-threads; into the inner thread is screwed the igniter C; into the outer thread works the screw-assembling disk *b*, which is prevented from turning when screwed down by the brass screw *e;* at the bottom of the brass stem and projecting from its center is a sharp projecting pin, *f*. The stem has on its exterior a grooved channel, and through it, near the point of pin *f*, radial holes, which permit the flame from fulminate to communicate with priming-chamber. The upper part A, or the "regulator" of the fuse, Fig. 6, is a ring of a truncated conical form; it has a priming-chamber and a circular groove on its under side, inclosing compressed mealed powder. The external opening of the chamber is covered by a thin strip of lead and tin, and the internal by a piece of paper. The rim of the "regulator" is divided into regularly-increasing spaces from 2 to 22, indicating meters and half meters. Separating A and B is a washer of felt. A channel, *g*, through the lower part of B, filled with rifle-powder, allows communication between the burning composition of fuse and powder charge of shell; the position of the upper opening of this channel is indicated on the rim of B by a triangular notch; the lower opening is closed by a disk of lead and tin, thin enough to be blown out by the rifle-powder.

The igniter C is composed of four parts—the brass *stock*, which incloses all; the *screw cap* H, which closes end, Fig. 8; the leaden-shouldered *plunger* K, Fig. 7, with its recess at bottom to receive the *fulminate wafer* L.

The fuse works as follows: At the instant of discharge the plunger, by its own inertia, is forced back, shearing off the soft shoulders, and the fulminate strikes the projecting pin-point; the resulting gas escapes through the radial holes around this point and into grooved channel, igniting the powder in priming-chamber and circular groove, which burns till the channel of rifle-powder is reached, when the thin disc of metal at bottom of channel is blown out, and the flame reaching powder in shell, explosion takes place.

Record of firing with German time-fuses, made at Sandy Hook August 30, 1877, *and August* 17, 1878.

[Rifle used: 3''.15 (8 centimeters) Bochum breech-loading rifle No. 1. Powder: 1 pound 2 ounces of Krupp's mortar. Shell: Krupp case-shot; weight, 10 pounds 8 ounces. Elevation: 1° 50', $\frac{7}{8}$°, $1\frac{1}{8}$°, and $1\frac{3}{8}$°.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	Struck 105 paces in front of target; burst in air 100 yards beyond target; fuse set for 1,000 meters, burst in 8 seconds.
2	Struck 25 paces in front of target; fuse set for 1,000 meters, burst in $6\frac{1}{8}$ seconds.
3	Struck 140 paces in front of target; fuse set for 800 meters, burst in $5\frac{1}{4}$ seconds.
4	Struck 132 paces in front of target; fuse set for 800 meters, burst in $9\frac{1}{4}$ seconds.
5	Struck 129 paces in front of target; fuse set for 800 meters, burst near point of striking.
6	Direct hit, 6' above center; fuse set for 800 meters, burst in 7 seconds.

Record of firing with German time-fuses, &c.—Continued.

No. of round.	Remarks.
7	Direct hit, $3\frac{3}{4}'$ above, 2′ right; fuse set for 800 meters, burst in $6\frac{3}{4}$ seconds.
8	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{3}{4}$ seconds.
9	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{3}{4}$ seconds.
10	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{1}{2}$ seconds.
11	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{1}{2}$ seconds.
12	Burst in air before reaching target; fuse set for 700 meters, burst in $3\frac{1}{2}$ seconds.
13	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{1}{2}$ seconds.
14	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{3}{4}$ seconds.
15	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{1}{4}$ seconds.
16	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{1}{4}$ seconds.
17	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{1}{2}$ seconds.
18	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{1}{2}$ seconds.
19	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{3}{4}$ seconds.
20	Burst in air before reaching target; fuse set for 700 meters, burst in $2\frac{1}{2}$ seconds.
	Fired down beach:
21	Fuse set for 500 meters, burst about 500 meters; time of flight, 2 seconds.
22	Fuse set for 700 meters, burst about 700 meters; time of flight, $3\frac{1}{2}$ seconds.
23	Fuse set for 700 meters, burst about 700 meters; time of flight, $3\frac{1}{2}$ seconds.
24	Fuse set for 1,000 meters; struck ground in front of 1,000-yard target, and burst in air 50 yards beyond.
25	Fuse set for 1,000 meters; struck ground 300 yards beyond 1,000-yard target, and ricochetted through mile target; did not burst.

M'INTYRE'S TIME FUSE, REAR.

(Plate IX.)

This fuse, inserted in the rear of the shell, consists of the brass stock A, time-fuse B, a brass screw-plug C, and lead igniting cap D. The fuse composition driven in a paper case is first inserted in the stock, the screw plug with a vertical hole, to one side of its center is screwed to touch top of fuse. The igniting cap with its channel of pressed powder composition is then inserted so that the under opening of channel shall communicate directly with the hole through screw-cap, which is also filled with the composition. Directly under the projection which rises above the top of the igniting cap is the upper opening to channel. Before firing, this projection is removed with a sharp knife and the composition thus exposed.

Record of firing with McIntyre's time-fuses, rear, made at Sandy Hook August 29 and September 18, 1877.

[Rifle used: 3″ wrought-iron rifle No. 965. Powder: $1\frac{1}{4}$ pounds of mortar. Shell: Butler; weight, 10 pounds. Elevation: $1\frac{5}{8}°$, $1\frac{3}{4}°$, $1\frac{7}{8}°$, and 5°.]

No. of round.	Remarks.
	Fired at 1,000-yard target; time of fuse believed to be 5 seconds:
1	Direct hit, 8′ left, 5′ below; did not explode.
2	Burst about 500 yards from gun.
3	Direct hit, $5\frac{1}{2}'$ below, 4′ left; burst in air about 600 yards beyond target.
4	Direct hit, 4′ left of center; burst in air about 300 yards beyond target.
5	Direct hit, 2′ left, $1\frac{1}{2}'$ below; burst in air about 400 yards beyond target.
6	Struck 70 paces in front of target; burst in air after striking ground.
7	Struck 45 paces in front of target; burst in air after striking ground.
8	Struck 65 paces in front of target; burst in air after striking ground.
9	Struck 34 paces in front of target; burst in air after striking ground.
10	Struck 57 paces in front of target; did not burst.
11	Fired over water; did not burst.
12	Fired over water; burst at muzzle.
13	Fired over water; burst in air about $\frac{3}{4}$ of a mile from gun.

GILL COMBINATION FUSE No. I.

(Plate X.)

The metal stock A of this fuse is open at both ends, the front half being bored conically to receive the time-fuse B. At the bottom of the recess for fuse B is a small disk of metal, C, having a vent-hole, D, through its center; about ⅛ of an inch below the disk C is a second and heavier one, E, having a central projecting point, F, on the under side; through this disk and equidistant from its center are three small holes. The space between disks is filled with pressed musket-powder, pieces of thin paper preventing its falling through holes in disks. The remainder of the stock A is bored cylindrically for the play of the triangular plunger G, the hole through center of which is surmounted by a percussion cap, H.

On one of the triangular edges of plunger G, is a single stud running full length of plunger; both of the other edges have two studs, so arranged that the ones in front shall be in a different plane to insure freedom at impact. The cylindrical hole M through plunger is filled with pressed musket-powder and end stopped by a leather plug. A safety pin, R, secures plunger in place. A metal pin, L, prevents plunger from falling out, and a paper washer closes the rear end of stock.

The fuse acts as follows: the time fuse B, cut for a certain number of seconds, is ignited at the instant of discharge by the gas from powder charge, and the flame from fuse composition ignites the pressed musket-powder between the disks C and E, which in turn ignites the bursting charge of shell. Should, however, the flight of the projectile be arrested before the burning out of fuse composition, the plunger G is thrown forward, the cap striking the projecting point F on disks E, igniting mealed powder in center of plunger G, this igniting the bursting charge and exploding the shell.

Record of firing with Gill's combination fuses No. 1, made at Sandy Hook July 21 and October 26, 1877.

[Rifle used: 3″ wrought-iron rifle No. 965. Powder: 1¼ pounds of old mortar. Shell: Dyer; weight, 8 pounds 15 ounces. Elevation 1⅝°.]

No. of round.	Remarks.
	Fired at 1,000-yard target for percussion:
1	Over target; did not explode.
2	Direct hit, 4′ above center; exploded on striking ground behind target.
3	Struck 38 paces in front of target; did not explode.
4	Direct hit, 3′ above, 7′ left; did not explode.
5	Struck 6 paces in front of target; did not explode.
	Fired along beach for percussion:
6	Burst in air; time, 2¾ seconds.
7	Did not burst.
8	Did not burst.
9	Burst in air; time, 2½ seconds.
10	Burst in air; time, 1¼ seconds.
11	Did not burst.
12	Did not burst.
	All 3-second time-fuses; fired along beach for time:
13	Did not burst.
14	Did not burst.
15	Did not burst.
16	Did not burst.
17	Burst in air; time, 2¾ seconds.
18	Did not burst.
19	Did not burst.
20	Did not burst.
21	Did not burst.
22	Did not burst.
23	Burst in air 900 yards from gun.
24	Did not burst.

GILL COMBINATION FUSE NO. 2.

(Plate XI.)

Consists of a metal stock, A, open at the rear but closed at the front end by a screw plug, B, having a transversal projection, C, on the out, and a central one, D, on the inside, both bored to form right-angled channels, which, when filled with pressed gunpowder, constitutes the igniter for time-fuse. At the bottom of the cylindrical pocket of the stock A there is a recess to receive the wedge-shaped, soft-metal valve or stopper-ring F, which is held, after being pressed tightly into place, by two pins G. The stock terminates in a slightly conical shaped projection bored to receive and hold securely the time-fuse H. The bottom of the recess for valve F is open, except at the three points or shoulders E. The screw-plug B is provided also with two holes KK through which may be passed a strand of quick match to insure ignition of time-fuse.

The operation of the fuse is as follows: The gas from the burning powder charge starts the igniter, which in turn ignites time-fuse—cut as desired; should the shell's progress be arrested before burning out of fuse, the soft-metal ring is thrown forward, allowing gas from burning fuse free communication with bursting charge in shell.

Record of firing with Gill's combination fuse No. 2, made at Sandy Hook August 29 and October 26, 1877.

Rifle used: 3″ wrought-iron rifle No. 965. Powder: 1¼ pounds of mortar. Shell: Dyer; weight, 8 pounds 15 ounces. Elevation: 1⅝°.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	3″ fuse; direct hit, 3½′ below, 1½′ left; fired for percussion; did not explode.
2	3″ fuse; exploded in air 80 paces in front of target; fired for time.
3	5″ fuse; exploded in air 100 paces in front of target; fired for time.
	Quick match used on igniter in all save the first.
4	5″ fuse; direct hit, 3½′ left of center; fired for percussion; exploded in air 200 yards beyond target after it had struck ground.
5	5″ fuse; direct hit, 5½′ below, 1½′ right; fired for percussion; did not explode.
	Fired along beach:
6	3″ fuse; burst in air 800 yards from gun; fired for time.
7	3″ fuse; burst on striking ground; fired for time.
8	3″ fuse; burst in air; time, 3 seconds; fired for time.
9	3″ fuse; burst on striking ground; fired for time.
10	3″ fuse; burst in air; time, 2¾ seconds; fired for time.
11	3″ fuse; burst in air; time, 3 seconds; fired for time.
12	3″ fuse; burst in air; time, 2¾ seconds; fired for time.
13	3″ fuse; burst in air; time, 2¾ seconds; fired for time.
14	3″ fuse; burst on striking ground; fired for percussion.
15	5″ fuse; burst in air; time, 3 seconds; fired for percussion.
16	5″ fuse; burst on striking ground; fired for percussion.
17	5″ fuse; burst on striking ground; fired for percussion.
18	5″ fuse; burst on striking ground; fired for percussion.
19	5″ fuse; burst on striking ground; fired for percussion.
20	5″ fuse; burst on striking ground; fired for percussion.
21	5″ fuse; burst on striking ground; fired for percussion.
22	5″ fuse; burst on striking ground; fired for percussion.
23	5″ fuse; burst on striking ground; second time fired for percussion.

O'REILLY COMBINATION FUSE.

(Plate XII.)

Consists of a metal stock, A, open at the rear, but closed at front end by a screw-cap, B, from which projects two studs CC for screwing and

unscrewing the cap. There are also two holes DD in screw-cap through which is passed and secured a strand of quick match, E.

The fuse F is tightly pressed into a conical shaped snug-fitting plunger, G, held in place by a wire, H, which passes through a hole, I, in side of stock and enters a cannelure on the plunger.

The operation of the fuse is as follows: At the instant of discharge the quick match is ignited by flame from charge of powder; this ignites the fuse, which continues to burn as an ordinary time-fuse; when the flight of the projectile is arrested, the plunger, by its inertia, is driven forward, sheering off the pin which holds it, and, being followed by loose powder in shell, ignition and explosion follow.

Record of firing with O'Reilly's combination fuses, made at Sandy Hook July 21 and October 26, 1877.

Rifle used: 3″ wrought-iron rifle No. 965. Powder: 1¼ pounds old mortar. Shell: Dyer; weight, 8 pounds 15 ounces. Elevation: 1⅝° and 5°.]

No. of round.	Remarks.
	Fired at 1,000-yard target, for percussion:
1	Struck 12 paces in front and burst, going through target.
2	Struck 142 paces behind target; burst in air after striking.
3	Direct hit, 4½′ left, 6′ below; exploded on striking behind target.
4	Right of target; exploded on striking.
5	Direct hit, 4½′ right, 3′ below; exploded on striking behind target.
	Fired along beach for time; 3 seconds time-fuse:
6	Did not burst.
7	Did not burst.
8	Did not burst.
9	Did not burst.
10	Did not burst.
11	Did not burst.
12	Did not burst.
13	Did not burst.
14	Did not burst.
15	Burst in air; time, 2½ seconds.
16	Did not burst.
17	Did not burst.
18	Did not burst.
19	Did not burst.
20	Did not burst.
21	Did not burst.
22	Did not burst.
23	Did not burst.

THOMPSON COMBINATION FUSE.

(Plate XIII.)

The time and percussion arrangement of this fuse are entirely independent of each other, the metal stock A being bored throughout its length on one side conically for the time-fuse B, and on the other cylindrically for the percussion device. The time-fuse is ignited by a plunger, E, which forms part of, and is secured to, the screw-cap C, by a brittle wire W, the lower end of this plunger being slightly recessed to receive a fulminate wafer H. The inner end of cap arrangement is turned under, forming a hollow cone. The percussion device or friction primer G consists of a brass tube, filled with friction composition pressed around a flat brass wire having serrated edges, the outer end of the wire being secured to a cylinder of thin brass which projects beyond the fuse-stock. The friction primer is provided with a screw-thread to secure it to stock,

and the channel D, into which it is screwed, is filled with quick-burning powder.

The action of the fuse is as follows: The shock of discharge frees the plunger, which, being thrown violently back, the fulminate H is ignited on cone, setting fire to time-fuse. Should the projectile strike before burning out of time-fuse, the wire in projecting primer G is driven through the friction composition, and the powder in channel D is ignited, the flame from which communicates directly with powder charge.

Record of firing with Thompson combination fuses, made at Sandy Hook August 3, 1877, *and May* 10, 1878.

[Rifle used: 3″ wrought-iron rifle No. 965. Powder: 1¼ pounds of mortar. Shell: Dyer; weight, 8 pounds 15 ounces. Elevation, ¾°, 1°, 1⅝°, and 5°.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	3 seconds; burst in air about 400 yards from gun; premature.
2	3 seconds; burst in air about 400 yards from gun; premature.
3	3 seconds; burst in air about 400 yards from gun; premature.
4	3 seconds; burst in air about 400 yards from gun; premature.
5	3 seconds; burst in air about 400 yards from gun; premature.
	After these five rounds had been fired the remainder of the fuses were sent to Frankford arsenal for alterations, at the request of Mr. Thompson.
	Fired over water, for time:
6	3 seconds; burst in air; time, 2¾ seconds.
7	3 seconds; burst in air; time, 2¼ seconds.
8	3 seconds; burst in air; time, 1¾ seconds.
9	3 seconds; burst in air; time, 1¾ seconds.
0	3 seconds; burst in air; time, 1¾ seconds.
	Fired at 440-yard target, for percussion:
11	5 seconds; burst going through target; time, 1¾ seconds.
12	5 seconds; burst at muzzle; premature.
13	5 seconds; went through target and burst on striking sand 40 yards beyond; time, 2¾ seconds.
14	5 seconds; burst going through target; time, 2 seconds.
15	5 seconds; burst near muzzle; premature; time, 1 second.
	Fired for percussion, striking ground about 600 yards from gun:
16	5 seconds; burst on striking sand; time, 2½ seconds.
17	5 seconds; burst at muzzle; premature.
18	5 seconds; burst in air after striking sand; time, 3¾ seconds.
19	5 seconds; burst in air immediately after striking sand; time, 2½ seconds.
	These 14 fuses were returned from Frankford arsenal, where alterations suggested by Mr. Thompson had been made. Before firing them, Colonel Burbridge, representing Mr. Thompson, requested still further changes, which were made in New York.

WARE COMBINATION FUSE NO. 1.

(Plate XIV.)

Consists of a metal stock, A, open at the rear, but closed at the front end by a screw-cap, B. The cap B is provided with four holes, two of them to receive the wrench for screwing and unscrewing it in and out of the shell, the other two for the pins D D, which fasten to the cap the igniter E, an annular piece of metal having four projecting points, marked L. The stock is bored cylindrically for nearly half its entire length, followed by a conical-shaped seat for the plunger F. The plunger and remainder of stock are bored slightly conical to receive and hold firmly the time-fuse G. Around the top rim of the plunger is cut an annular channel to receive the fulminate wafer H.

The fuse works as follows: Upon movement of the shell, the igniter E frees itself from the cap B, moves down upon plunger F, and its point,

striking fulminate wafer H, ignites the fuse G, when motion of shell is arrested, the plunger F, fuse G, igniter E, and loose powder in shell move forward to cap B, the igniter E closing the four small radial air-holes K in head of stock, preventing water and dirt from entering and extinguishing fuse. This forward movement of fuse and plunger allows gas from fuse composition free communication with interior of shell, to further facilitate which small radial holes, M and N, are bored in plunger and stock.

Record of firing with Ware's combination fuses No. 1, made at Sandy Hook, August 3, 1877, and March 11, 1878.

[Rifle used: 3″ wrought-iron rifle No. 965. Powder: 1¼ pounds of mortar. Shell: Dyer; weight, pounds 15 ounces. Elevation: 1°, 1¼°, 1⅜°, and 10°.]

No. of round.	Remarks.
	Fired to strike in front of 1,000-yard target:
1	3 seconds; burst in air about 300 yards from gun.
2	3 seconds; struck 15 paces in front of target; burst on striking.
3	3 seconds; direct hit, 3′ 6″ below, 6″ to left; did not burst.
4	3 seconds; direct hit, 8″ right, 3′ above; burst in air after striking ground.
5	3 seconds; exploded in air about 500 yards from gun.
6	3 seconds; fired down beach for time; burst in air; time, 2½ seconds.
7	3 seconds; fired down beach for time; burst in air; time, 2¾ seconds.
8	4 seconds; fired at 1,000-yard target for percussion; burst in air; time, 2 seconds.
9	5 seconds; fired at 1,000-yard target for percussion; burst on striking ground; time, 2¾ seconds.
10	5 seconds; fired at 1,000-yard target for percussion; passed through target and burst in air after striking ground; time 5¼ seconds.
11	5 seconds; fired down beach for time; burst in air after striking ground; time, 10¾ seconds.
12	5 seconds; fired down beach for time; burst in air after striking ground; time, 7¼ seconds.
13	5 seconds; fired down beach for time; burst in air after striking ground; time, 5¾ seconds.
14	5 seconds; fired down beach for time; burst in air after striking ground; time, 4 seconds.
15	5 seconds; fired over water for time; burst in air; time, 4¼ seconds.
16	5 seconds; fired over water for time; burst in air; time, 5¼ seconds.

WARE COMBINATION FUSE NO. 2.

(Plate XV.)

Consists of a metal stock, A, closed at upper end by a screw-cap, B; on the shoulder C, near the bottom of the cylindrical space in the stock, rests a metal ring D, having a recess turned in its upper surface to receive the fulminate wafer E; between the ring and shoulder lies a soft metal ring or gas-check, F. The plunger G, bored slightly conically to receive the time-fuse H has at its upper end four projecting arms I, terminating on the under side in sharp points K. From the bottom of the stock projects the four points L. To the lower end of the plunger is secured a metal ring M, on the upper surface of which is cut a recess to receive the fulminate wafer N (like E). The plunger is held in place by the safety-pin O. There are also in the projecting end of stock four radial holes P, for escape of gas.

The fuse is intended to act as follows: When the projectile is set in motion, the plunger by its inertia is carried back, sheering off the safety-pin O; the projecting points K strike the fulminate E, which ignites the time-fuse.

When its motion is arrested the plunger moves forward bringing the metal ring M and fulminate N against the sharp points L, igniting powder charge, which is also thrown forward and surrounds the ring.

Record of firing with Ware's combination fuses No. 2, made at Sandy Hook, August 3 and 4, 1877.

[Rifle used: 3″ wrought-iron rifle No. 965. Powder: 1¼ pounds of mortar. Shell: Dyer; weight, 8 pounds 15 ounces. Elevation: 1⅝°.]

No. of round.	Remarks.
	Fired to strike in front of 1,000-yard target:
1	3 seconds; burst at muzzle.
2	3 seconds; burst in air about 50 yards from gun.
3	3 seconds; burst at muzzle.
4	Lower percussion ring taken off; burst at muzzle.
5	Fuse not altered; burst at muzzle.
	After firing the above the balance were withdrawn.

TREADWELL COMBINATION FUSE.

(Plate XVI.)

This is a modification of the Splingard fuse, and consists of the following parts: A metal fuse plug, E; a paper case, A, into which the fuse composition B is driven around a mandrel, a leaden corrugated cylinder, C, being left as a lining of the fuse composition after the mandrel is withdrawn; a tube, D, closed at the front end, is now made by pouring fluid plaster of Paris, or this with asbestos mixed.

The theory of the fuse being that the fuse composition burning down leaves the plaster Paris tube unsupported, and at impact the closed end is broken off, giving the flame of the fuse access to the bursting charge of the projectile.

Record of firing with Treadwell combination fuses, made at Sandy Hook, August 4 and September 20, 1877.

[Rifles used: 4½″ siege rifle No. 101; 3″ wrought-iron rifle No. 965; 4½″ siege rifle No. 101. Powder: 3¼ pounds new mortar E. Z. Shell: Absterdam; weight, 24¼ pounds. Elevation: 5° and 10°.]

No. of round.	Remarks.
1	Fired over water; fuse set at 5″; burst in 3½″; fired for time.
2	Fired over water; fuse set at 5″; burst in 2½″; fired for time.
3	Fired over water; fuse set at 10″; burst in 2″; fired for time.

[3″ wrought-iron rifle No. 965. Powder: 1¼ pounds mortar. Shell: Dyer; weight, 8 pounds 15 ounces. Elevation: 1⅝°.]

	Fired at 1,000-yard target, for percussion:
1	Fuse set at 3 seconds; burst in air about 100 yards from gun.
2	Fuse set at 3 seconds; burst in air about 100 yards from gun.
3	Fuse set at 4 seconds; burst in air about 50 yards from gun.
4	Fuse set at 5 seconds; burst in air about 200 yards from gun.
5	Fuse set at 5 seconds; burst in air about 300 yards from gun.

RUBEN AND FORNEROD (SWISS) COMBINATION FUSES.

(Plates XVII and XVIII.)

These two fuses are alike in principle, and differ only in that the larger one (Plate XVII) has two tiers of burning composition and is capable of burning 20 seconds, twice the length of time—as a time-fuse—that the smaller one (Plate XVIII) can burn.

The fuses consist of three principal parts, the body A, the inertia igniter B, and the percussion-fuse attachment C. A and B constitute the time-fuse. The former is made of an alloy of equal parts of lead and tin, while B and C are of brass. The body A is provided on its exterior with a screw-thread, by means of which it is connected with the shell; the central cylindrical part is also provided with a screw-thread, into which fits the assembling screw of igniter B, which binds all the different parts of the time-fuse together.

The body A of the larger fuse (Plate XVII) is composed of three parts, *a*, *b*, and *c* (Figs. 3, 4, and 5); the upper part *a*, or the regulator (Fig. 3), is a ring of truncated form; it has a priming chamber, and a channel on its under side, inclosing compressed mealed powder. The chamber opens externally upon a thin part of the wall and internally upon the core. The channel is covered by a disk of foil. The rim of the regulator *a*, is divided into 50 equal parts, each one representing one-fifth of a second. The part *b* (Fig. 4) has also a chamber and similar channel of compressed mealed powder; the chamber opening on top for communication with the channel of *a*, and on the outside for escape of gas, the outside opening being covered with wax. Between *a* and *b* and glued to the top of *b* is a washer of thick cloth with a small hole through it just over opening to chamber of *b*. The lower part *c* (Fig. 5) has on its under side a circular channel of rifle-powder covered by a perforated disk of copper—a piece of gauze separates the powder and copper ring; a vertical channel filled with rifle-powder allows a communication between powder in *b* and the rifle-powder in *c*; separating *b* and *c*, and glued to top of latter, is a washer of cloth exactly similar to one separating *a* and *b*. The outside rim of this piece is also graduated into 50 equal parts, each one reading one-fifth of a second.

The igniter B (Figs. 2 and 6) consists of three parts, *d*, *e*, *f*, and *g*; the stock *d* has a cylindrical cavity, at the center of the bottom of which projects a sharp pin-point; four radial holes at bottom of cavity allows the gas from igniter to escape and spread into a circular groove around the outside of the stock; a brass washer separates the hexagonal rim of the head of the stock from the regulator or part *a* of the body. At the bottom of the stock there is a cylindrical projecting cup filled with the same composition as that in the igniter, and also covered with a solution of rubber. The cylindrical plunger *e* (Fig. 7) has in the center of its base a recess which contains the fulminate priming, which is believed to be made of five parts chlorate of potassa, one of sulphide of antimony, and one of powdered glass, all coated with a solution of rubber; the crown-shaped spring *f* (Fig. 8) is stamped out of a thin piece of steel; it has four spring leaves; the bottom of the spring is shaped to fit the base of the plunger and to expose the fulminate in plunger; the screw-cap *g* closes the top of the stock *d*; a hole through its center allows the cylindrical projection on top of plunger to pass through and centers the plunger in spring and cylindrical cavity of stock.

The percussion attachment C consists of five parts, *h*, *k*, *m*, *n*, *o*; the hollow cylindrical stock *h* (Fig. 9) has a solid bottom, pierced with a

small central hole for passage of gas from the fulminating composition into the shell; this hole is closed by a piece of fine netting, or gauze, to prevent the powder in the shell from penetrating fuse-stock or body; a shoulder turned on its exterior fixes its position in the fuse-hole of shell; the cylindrical plunger K (Fig. 10) has through its axis a longitudinal channel, at the head of which is secured a sharp steel projecting point; forward movement of the plunger, except upon impact in flight, is prevented by a steel crown-shaped spring *m*, (Fig 11), similiar to the one heretofore described. A hollow cylinder *n*, (Fig. 12), centers the plunger and is just long enough to permit the pin point to reach and pierce the fulminate on impact; the stock is closed by a brass ring *o*, resting on a shoulder turned in top of stock.

The action of the combination is as follows: Upon the inflammation of the charge, the plunger is thrown back, the spring being compressed, and the plunger, with its fulminate, strikes the metallic point; the gas due to the consequent ignition passes through the openings in the wall of the tube, spreads into the circular groove around the outside of the tube, ignites the priming of the burning column, and thus causes the inflammation of the section of this column in contact with it; inflammation spreads along the burning prism, and, reaching its origin, is communicated to the second tier (if fuse is set for more than 10 seconds), and so on to the chamber and recess of rifled powder which communicates with the powder in shell.

The combustion of the priming of compressed powder produces sufficient heat to melt the thickness of metal which closes the priming-chamber, and thus affords a broad outlet to the gas from the burning column. From experiments made in Switzerland, it is believed these fuses offer entire security against premature ignition, the shells being given the most violent shocks which could be received in transportation, loading, or unloading. The ignition is very certain, even with reduced charges.

Should the fuse strike any resisting object before the burning composition has reached the point to which the time-fuse was set, the plunger or percussion attachment C, is thrown forward, the spring being compressed, and the pin point pierces the fulminate at base of igniter B, and the gas resulting has direct access to bursting charge of shell.

(Plate XVIII.)

The smaller fuse has the same general features as the larger; it differs from it in that it has but one layer of composition, which burns 10 seconds.

The body A is in two parts only; the regulator *a* (Fig. 3) with its circular groove of compressed mealed powder has on its outside rim 50 equal divisions representing fifths of seconds. The lower part of the *b*, (Fig. 4) covers the percussion attachment C, and has running vertically through one side a hole filled with rifle-powder; this is the channel of communication between burning composition of time-fuse and bursting charge of shell. The conical outside surface of the igniter B, is roughened to facilitate turning of the assembling screw which binds the different parts of the fuse; by loosening and tightening this screw the regulator is set to the required time. The different parts of this fuse function as those of the larger fuse.

Record of firing with Reuben & Fornerod's combination fuses No. 1, *made at Sandy Hook August* 14, 1878.

[Rifle used: 4½″ siege rifle No. 101. Powder: 3¼ pounds of experimental C. Shell: Absterdam; weight 24 pounds. Elevation: 1⅝°, 10°, 13½°, and 15°.]

No. of round.	Remarks.
	Fired over water for time:
1	Fuse set at 11 seconds; burst in air; time, 9 seconds.
2	Fuse set at 12 seconds; burst in air; time, 9½ seconds.
3	Fuse set at 14 seconds; burst in air; time, 11 seconds.
4	Fuse set at 16 seconds; burst on striking water; time, 12¼ seconds.
5	Fuse set at 18 seconds; burst in air; time, 14½ seconds.
6	Fuse set at 20 seconds; burst in air; time, 20 seconds.
	Fired at 1,000-yard target for percussion:
7	Fuse set for percussion; through 1,000-yard target; struck ground beyond, ricochetted through mile target; struck ground once and water once; did not burst.
8	Fuse set at 5 seconds; through target; struck ground once and water once; did not burst.
9	Fuse set at 3 seconds; through target; burst on striking ground beyond.
10	Fuse set at 5 seconds; through target; burst on striking ground beyond.
11	Fuse set at 8 seconds; through target; burst on striking ground beyond.
12	Fuse set at 5 seconds; through target; burst on striking ground beyond.

Record of firing with Reuben & Fornerod's combination fuses No. 2, *made at Sandy Hook August* 14, 1878.

[Rifle used: 4½″ siege rifle No. 101. Powder: 3¼ pounds of experimental C. Shell: Absterdam; weight, 24 pounds. Elevation: 1⅝° and 10°.]

No. of round.	Remarks.
	Fired over water for time:
1	Fuse set at 3 seconds; burst on striking water; time, 13½ seconds.
2	Fuse set at 4½ seconds; burst on striking water; time, 13 seconds.
3	Fuse set at 5 seconds; burst on striking water; time, 13½ seconds.
4	Fuse set at 6½ seconds; burst in air; time, 4¾ seconds.
5	Fuse set at 8½ seconds; burst on striking water; time not taken.
6	Fuse set at 10 seconds; burst in air; time, 10 seconds.
	Fired at 1,000-yard target for percussion:
7	Fuse set at 6 seconds; through target; burst on striking ground beyond.
8	Fuse set at 6 seconds; through target; burst on striking ground beyond.
9	Fuse set at 4 seconds; through target; burst on striking ground beyond.
10	Fuse set at 4 seconds; through target; burst on striking ground beyond.
11	Fuse set at 4 seconds; struck ground 10 feet in front of target and burst.
12	Fuse set at 4 seconds; struck ground 15 feet in front of target and burst.

M'INTYRE'S COMBINATION FUSE, REAR.

(Plate XIX.)

The fuse is identical with McIntyre's time-fuse, previously described and shown in Plate IX, except that there is inserted in the fuse composition a plunger E whose head is of lead and whose tapering stem is of brass; immediately surrounding the stem of the plunger is a column of plaster of paris, between which and the composition is a tube of fusible metal. Should the projectile in which the fuse is inserted strike a resisting object before the fuse composition has burned out, the plunger is thrown forward into the shell, giving flame from burning composition direct access to powder in shell.

Record of firing with McIntyre combination fuses, rear, made at Sandy Hook, July 13, *August* 29, *September* 18, *and December* 4, 1877.

[Rifle used: 3″ wrought-iron rifle, No. 965. Powder: 1¼ pounds of mortar. Shell: Butler; weight, 10 pounds 7 ounces and 10 pounds. Elevation. 1⅝°, 1¾°.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	Struck 120 paces in front of target; did not explode.
2	Struck 100 paces in front of target; did not explode.
3	Struck 120 paces in front of target; did not explode.
4	Struck 210 paces in front of target; did not explode.
5	Exploded in air about 300 paces in front of target.
6	Direct hit, 3′ left, 4½′ below; burst on striking ground.
7	Struck 15 paces in front of target; burst in air about 500 yards beyond target.
8	Direct hit, 2′ left, 1½′ below; did not explode.
9	Direct hit, 1⅜′ right of center; did not explode.
10	Direct hit, 1¾′ right of center; did not explode.
11	Struck 250 paces in front of target; did not explode.
12	Struck 160 paces in front of target; burst after striking ground second time.
13	Struck 175 paces in front of target; did not explode.
14	Struck 140 paces in front of target; did not explode.
15	Struck 30 paces in front of target; did not explode.
	Fired for time:
16	Burst at muzzle.
17	Fuse set at 5″; burst in air after striking ground in 5½″.
18	Fuse set at 5″; burst at muzzle.
19	Fuse set at 5″; failed to explode.
20	Fuse set at 5″; burst at muzzle.

Record of firing with Woodbridge combination fuses, made at Sandy Hook, December 4, 1877, *and March* 16 *and June* 14, 1878.

[Rifle used: 3″ wrought-iron rifle, No. 965. Powder: 1¼ pounds of old mortar. Shell: Butler; weight, 10 pounds. Elevation, 1¼°, 1½°, 1⅝°, 1⅞°, 2°, 3°, 5°, 6°, 10°.]

No. of round.	Remarks.
1	Fired over water; fuse set at 5″; burst in air in 5⅛″; fired for time.
2	Fired over water; fuse set at 5″; burst in air in 5″; fired for time.
3	Fired at 1,000-yard target; fuse set at 4″; burst in air in 5⅛″; fired for time.
4	Fired at 1,000-yard target; fuse set at 3½″; burst in air after striking ground in 3¾″.
5	Fired at 1,000-yard target; fuse set at 5″; burst in air after striking ground in 5″.
6	Fired at 1,000-yard target; fuse set at 5″; burst in air before striking ground; time, 2¼″.
7	Fired at 1,000-yard target; fuse set at 5″; burst in air after striking ground; time, 5¼″.
8	Fired at 1,000-yard target; fuse set at 5″; burst in air after striking ground; time, 5⅛″.
9	Fired at 1,000-yard target; fuse set at 5″; burst in air after striking ground; time, 6″.
10	Fired over water for time; fuse set at 10″; burst in air; time, 10¼″.
11	Fired over water for time; fuse set at 10″; burst in air; time, 8¼″.
12	Fired at 1,000-yard target; fuse set at 4″; burst in air after striking ground; time lost.
13	Fired at 1,000-yard target; fuse set at 4½″; burst in air after striking ground; time, 5½″.
14	Fired at 1,000-yard target; fuse set at 3¾″; burst in air after striking ground; time, 4¼″.
15	Fired at 1,000-yard target; fuse set at 4¼″; burst in air after striking ground; time, 4¾″.
16	Fired over water for time; fuse set at 7½″; burst in air; time, 10″.
17	Fired over water for time; fuse set at 8½″; burst in air; time, 9¾″.
18	Fired at 1,000-yard target; fuse set at 10″; struck ground about 40 paces in front of target and burst in air about 800 yards beyond.
19	Fired over water for time; fuse set at 4½″; burst in air; time, 5″.
20	Fired over water for time; fuse set at 9″; burst in air; time, 4½″.
21	Fired over water for time; fuse set at 6″; burst in air; time, 6¾″.
*22	Fuse set at 10″; fired over water for percussion; struck water three times; time of last striking, 13″; did not burst.
23	Fuse set at 10″; fired down beach for percussion; securing-pin weakened before firing; struck ground 30 paces in front of target; ricochetted through target; struck water once; did not burst.

* Twenty-second round not included in summary. End of paper inclosing time-fuse used for the eighteenth, twenty-second, and twenty-third rounds showed discoloration, due to oil.

PLUMACHER'S PERCUSSION-FUSE.

(Plate XXI.)

This fuze consists of a tube the interior of which has three peculiar-shaped communicating chambers of different sizes, a screw-cap, a screw-bottom, a winged needle-discharging plunger in the upper chamber, and a charged plunger in the lower chamber, the two plungers being kept apart by the third smaller or intervening chamber, as will be shown by reference to Plate XXI.

Fig. 1 is a vertical section of the charged fuse in repose, top end up. Fig. 2 is a vertical section of the charged fuse at the point of striking, after having been discharged from the gun, top end down. Fig. 3 is a vertical section of the empty fuse-case. Fig. 4 is a plan of a steel spring as cut from the sheet. Fig. 5 is an edge elevation of the steel spring bent for use. Fig. 6 is the needle or discharging-plunger, the spring fixed. Fig. 7 is an elevation and plan of the percussion-plunger.

In external appearance the fuse-tube A is an ordinary cylinder, having a screw-thread *t*, cut to a proper depth at one end on the periphery of the projectile. It is made of the size usual for percussion-fuses, so that it may be used in any pattern of elongated shell. The cavity of this cylinder is tapped at both top and bottom at *v v'*, and is provided with a screw-cap D, and a screw-bottom E, and the interior is divided, by abutting shoulders *o o*, into three different-sized chambers *f*, *g*, and *h*, in which the sliding plungers operate. The screw-cap D, has a groove, *r*, that it may be handled by a screw-driver, and an indent, *s*, on the lower side, to admit the point *x* of the needle *m*, should it be deemed necessary to reverse the discharge-plunger when shipping the projectile. The screw-bottom E, has key-holes *u u*, by which it is screwed, &c., and an escape-hole *e'*, through its axis, to permit the passage of fire into the magazine of the shell. The discharging-plunger B, is a cone-crowned piece of metal, smaller in diameter than either of the chambers, with a tapped hole, *c*, in the apex, into which a pointed steel needle *m*, is screwed, holding in place by a shoulder on the needle a many-pointed steel spring *k*. The steel spring *k* is just sufficiently stiff to hold the plunger in place and to prevent it from being forced into the center or chamber *g*, by any power less than the impact produced by the discharge of the projectile from the gun. The plunger is contained, needle-point down, in chamber *f*, but by the impact produced by the discharge of the gun it is thrown forward and secured by the flaring springs in chamber *g*. Sliding plunger C, incased in chamber *h*, larger and heavier than the plunger B, is of cylindrical shape—a body of metal with a cone-shaped crown, having through its axis a hole *e*, in which is secured, by a drop of varnish or other suitable material, the fulminating powder or pill *d*. Through this hole, also passes the fire into the magazine of the shell.

Extra security in transportation may be obtained by unscrewing the cap D and taking out and reversing the needle-plunger B, securing the point *x* of the needle *m* in the indent *s* in the lower side of the cap.

When fired, the impact produced upon the projectile by discharging the gun from which it was thrown forces plunger B, from its normal position into center chamber *g*, where it is held, at the bottom, by the narrow entrance to the lower chamber, and from the top by the ends of the many-pointed spring coming in contact with projecting shoulder *o o*, dividing chamber *f* from *g*, the point of the needle *m* protruding into the larger chamber *h*. Then, by the check on the projectile when striking, plunger C is thrown violently forward on to plunger B, the point of the needle *m* entering and discharging the pill or fulminating-powder *d*, thereby exploding the shell. (See Fig. 2.)

Record of firing with Plumacher percussion-fuses, made at Sandy Hook, December 14, 1877.

[Rifle used: 3" wrought-iron rifle, No. 965. Powder: 1¼ pounds of old mortar. Shell: Hotchkiss case-shot; weight, 8 pounds 8 ounces. Elevation, 1⅝°.]

No. of round.	Remarks.
	Fired at 1,000-yard target:
1	Struck sand three times and water twice; did not burst.
2	Burst at muzzle.
3	Burst on striking ground.

RESULTS OF FIRING.

In testing the fuses submitted, the Board decided to fire five preliminary rounds, noting results, and if any defects in workmanship should be developed, particularly in those of new construction, that the parties presenting the fuses should be notified, in order that the defects noted might be, if possible, corrected. Under this ruling the Gill No. 1, Ware, Thompson, and McIntyre fuses were returned for alterations. The Ware No. 2 was, after the 5th round, withdrawn; the others were returned and the firing continued.

An examination of the records of firing and general summary of tests appended, shows that in the firings at Sandy Hook the fuses stood as follows in order of merit:

Percussion.	Time.	Combination. (In order of merit as time-fuses.)	Combination. (In order of merit as percussion-fuses.)
1. German.	1. German.	1. Woodbridge.	1. Ruben & Fornerod (Swiss) No. 2.
2. Hotchkiss.	2. Lissberger.	2. Gill No. 2.	2. O'Reilly.
3. English (R. L.).	3. McIntyre.	3. Ware No. 1.	3. Woodbridge.
4. Schenkl.		4. Thompson.	4. Gill No. 2.
5. Eggo.		5. Ruben & Fornerod (Swiss) No. 2.	5. Thompson.
6. Absterdam.		6. Ruben & Fornerod (Swiss) No. 1.	6. Ruben & Fornerod (Swiss) No. 1.
7. English (Pettman).		7. McIntyre.	7. Ware No. 1.
8. Lissberger.		8. Gill No. 1.	8. Gill No. 1.
		9. O'Reilly.	9. McIntyre.

CONCLUSIONS.

The board is of opinion, from the limited trials made, as recorded in the journal of firing, that no well established superiority exists in several of these fuses, but the percentage of failures are so great in some cases that it would be useless to go to the expense of making further trials with them; it is, however, recommended that of the *percussion and time fuses* the following kinds only be procured for further tests, to wit:

Percussion.—German, Hotchkiss, English R. L., Schenkl.
Time.—German.

As regards the *combination-fuses*, no one of them may be said to have worked well; the Woodbridge and Gill No. 2, however, did considerably better than the others, and the board recommends that 25 more of each of these be made, with such improvements as Dr. Woodbridge and Mr. Gill may suggest, at Frankford arsenal, for further tests.

As to the other fuses of this character, they are generally complicated and expensive, so that the board only recommends their further trials provided they are furnished without cost to the United States.

APPENDIX.

Summary of test of percussion-fuses made at Sandy Hook, from July 13, 1877, to August 14, 1878.

Date.	Gun.	Powder.		Projectile.			Total No. of rounds.	Kind of fuse.	Shell.			Percentage of failures.	Remarks.
		Kind.	Charge, pounds.	Kind.	Weight.				Number burst on 1st impact.	Number burst on 2d or 3d impact.	Number failed.		
					Pounds.	Ounces.							
July 21 and Aug. 31, 1877	3" wrought-iron rifle, No. 965	Old mortar	1¼	Dyer	8	15	25	Hotchkiss	22	....	3	12	
July 13 and Aug. 31, 1877	....do	Mortar	1¼	...do	8	15	25	Schenkl	18	3	4	16	
Aug. 30, 1877	4½" siege rifle, No. 101	New mortar, E. Z.	3¼	Absterdam	24	4	25	Absterdam	8	....	17	68	
July 13 and Sept. 6, 1877	3" wrought-iron rifle, No. 965	Mortar	1¼	Dyer	8	15	24	Eggo	9	1	14	58⅓	
Aug. 31, 1877	3".15 (8 cm.) Bochum rifle	Krupp's mortar	1⅛	Krupp	9	4	20	German	19	....	1	5	
Aug. 8 and 14, 1878	3" wrought-iron rifle, No. 965	Mortar	1¼	Dyer	8	15	23	Pettman	7	....	16	69½	
Aug. 8 and 14, 1878	......do	...do	1¼	...do	8	15	23	General service, R. L.	19	1	3	13	
May 20, 1878	......do	Old mortar	1¼	...do	8	15	23	Lissberger	6	....	17	74	
Dec. 14, 1877	......do	...do	1¼	Hotchkiss case-shot	8	8	3	Plumacher	1	....	2	66⅔	Thrown out.

Summary of test of time-fuses made at Sandy Hook, from August 29, 1877, to August 17, 1878.

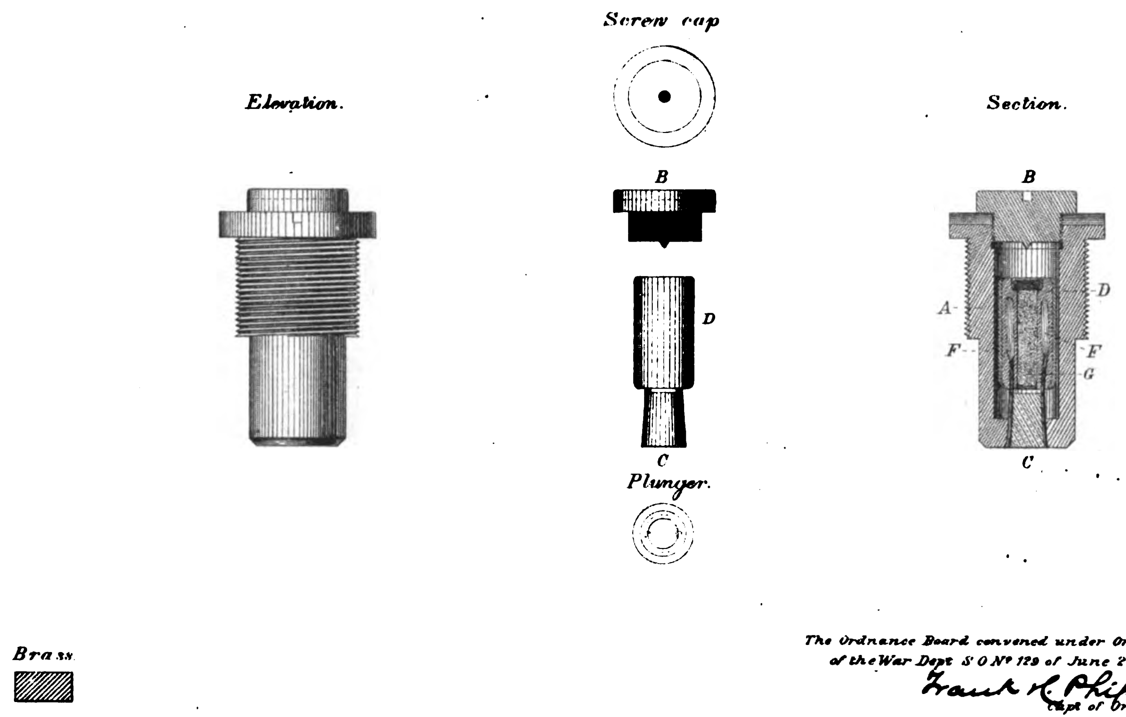
Date.	Gun.	Powder.		Projectile.			Total No. of rounds.	Fuse.		Percentage of failures.	Remarks.
		Kind.	Charge, pounds.	Kind.	Weight.			Kind.	Number thrown out—failed.		
					Pounds.	Ounces.					
May 20, 1878	3" wrought-iron rifle, No. 965	Old mortar	1¼	Dyer	8	15	4	Lissberger	1	25	All fuses not exploding within 2 seconds, plus or minus, of the time for which they were set, were thrown out in the general average.
Aug. 30, 1877, and Aug. 17, 1878	3".15 (8 cm.) Bochum rifle	Krupp's mortar	1⅛	Krupp's case-shot	10	8	25	German	1	4	
Aug. 29 and Sept. 18, 1877	3" wrought-iron rifle, No. 965	Mortar	1¼	Butler	10	....	*13	McIntyre	5	38½	

*Supposed to be 5-second fuses.

Summary of test of combination-fuses made at Sandy Hook, from July 13, 1877, to August 14, 1878.

Date.	Gun.	Powder. Kind.	Powder. Charge, pounds.	Projectile. Kind.	Projectile. Weight. Pounds.	Projectile. Weight. Ounces.	Total No. of rounds.	Fuse. Kind.	Fuse. No. fired. As time.	Fuse. No. fired. As percussion.	Fuse. No. failed. On time.	Fuse. No. failed. On 1st impact.	Fuse. Burst on 2d impact.	Percentage of failures on time.	Percentage of failures on percussion.	Remarks.
July 21 and Oct. 26, 1877	3″ wrought-iron rifle, No. 965.	Old mortar	$1\frac{1}{2}$	Dyer	8	15	24	Gill, No. 1	12	12	10	11	....	$83\frac{1}{3}$	$91\frac{2}{3}$	All fuses not exploding within 2 seconds, plus or minus, of the time for which they were set, were regarded as failures.
Aug. 29 and Oct. 26, 1877	....do	Mortar	$1\frac{1}{2}$	Dyer	8	15	23	Gill, No. 2	10	13	2	4	1	20	31	
July 21, and Oct. 26, 1877	....do	Old mortar	$1\frac{1}{2}$	...do	8	15	23	O'Reilly	18	5	17	0	....	$94\frac{4}{9}$	0	
Aug. 3, 1877, and May 10, 1878	....do	Mortar	$1\frac{1}{2}$	...do	8	15	19	Thompson	10	9	5	3	....	50	$33\frac{1}{3}$	
Aug. 3, 1877, and Mar. 11, 1878	....do	....do	$1\frac{1}{2}$	...do	8	15	16	Ware, No. 1	8	8	2	4	....	25	50	
Aug. 3 and 4, 1877	....do	....do	$1\frac{1}{2}$	...do	8	15	5	Ware, No. 2	0	5	0	5	....	....	100	Withdrawn.
Aug. 4 and Sept. 20, 1877	....do	....do	$1\frac{1}{2}$	...do	8	15	5	Treadwell	0	5	0	5	....	....	100	
	$4\frac{1}{2}$″ siege-rifle, No. 101.	New mortar, E. Z	$3\frac{1}{2}$	Abstordam	24	4	3	....do	3	0	2	0	....	$66\frac{2}{3}$	....	
Aug. 14, 1878	....do	Experimental 'C'	$3\frac{1}{2}$	...do	24	....	12	Ruben & Fornerod's, No. 1.	6	6	4	2	....	$66\frac{2}{3}$	$33\frac{1}{3}$	
Aug. 14, 1878	....do	Experimental 'C'	$3\frac{1}{2}$	...do	24	....	12	Ruben & Fornerod's, No. 2.	6	6	4	0	....	$66\frac{2}{3}$	0	
July 13, Aug. 29, Sept. 18, and Dec. 4, 1877.	3″ wrought-iron rifle, No. 965.	Mortar	$1\frac{1}{2}$	Butler	10	7	20	McIntyre	5	15	4	14	1	80	93	
Dec. 4, 1877, and Mar. 16 and June 14, 1878.	....do	Old mortar	$1\frac{1}{2}$	...do	10	....	22	Woodbridge	10	12	2	3	....	20	25	

HOTCHKISS'S PERCUSSION FUSE.

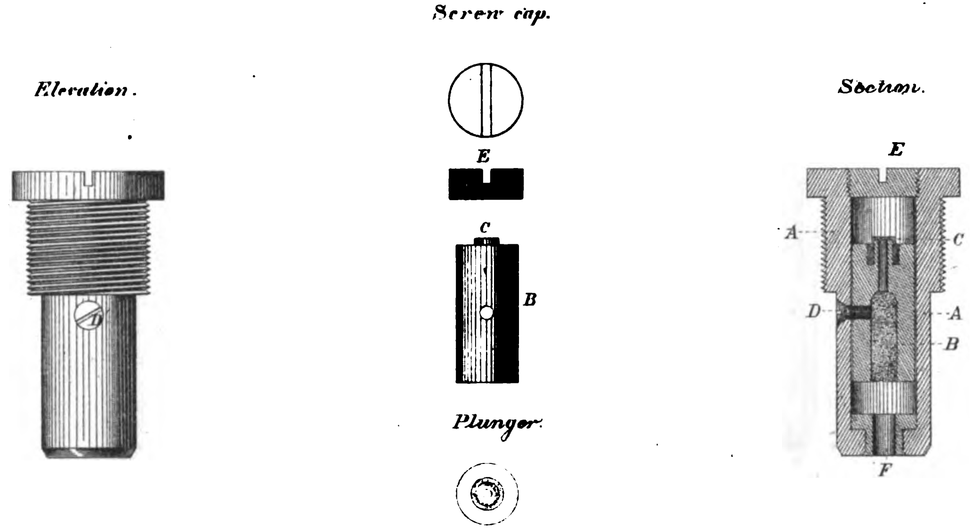


The Ordnance Board convened under Orders of the War Dept S. O. No 129 of June 27-1876

Frank H. Phipps
Capt of Ordnance
Recorder

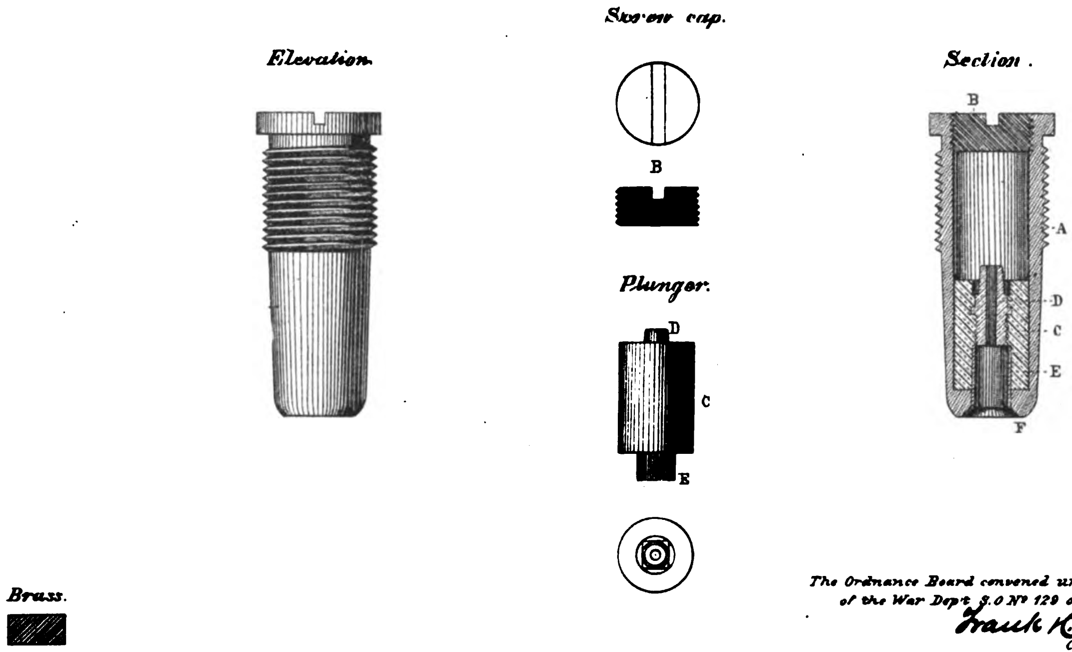
Accompanying Appendix 8[a], 1878

SCHENKEL'S PERCUSSION FUSE.



The Ordnance Board convened under Orders
of the War Dept S. O. Nº 129 of June 27-1876
Frank H. Phipps.
Capt of Ordnance
Recorder.

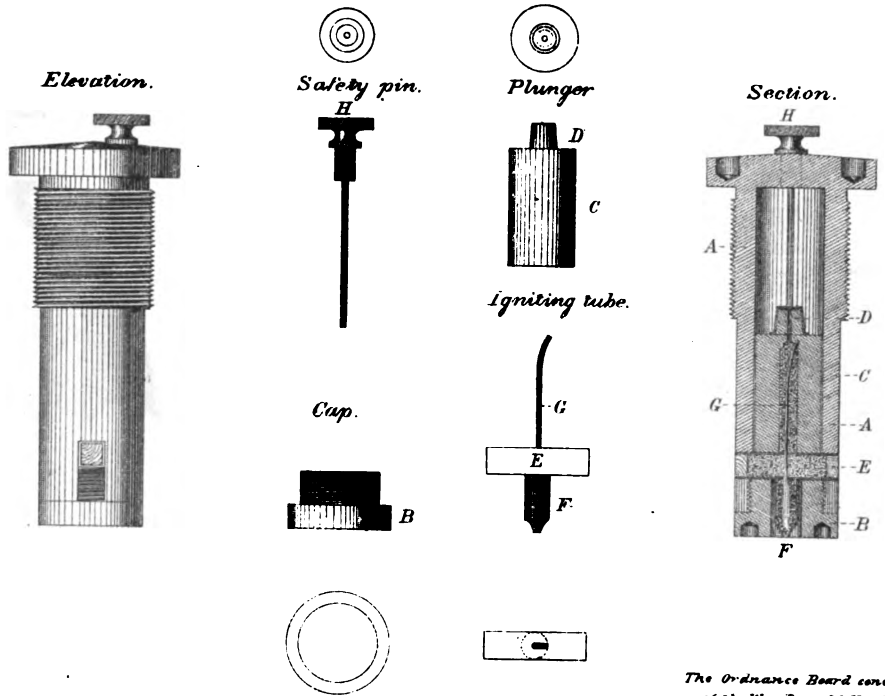
ABSTERDAM'S PERCUSSION FUSE.



The Ordnance Board convened under Orders of the War Dep't S.O. No 129 of June 27 – 1876.
Frank H. Phipps.
Cap't of Ordnance
Recorder.

PLATE III.

EGGO'S PERCUSSION FUSE.



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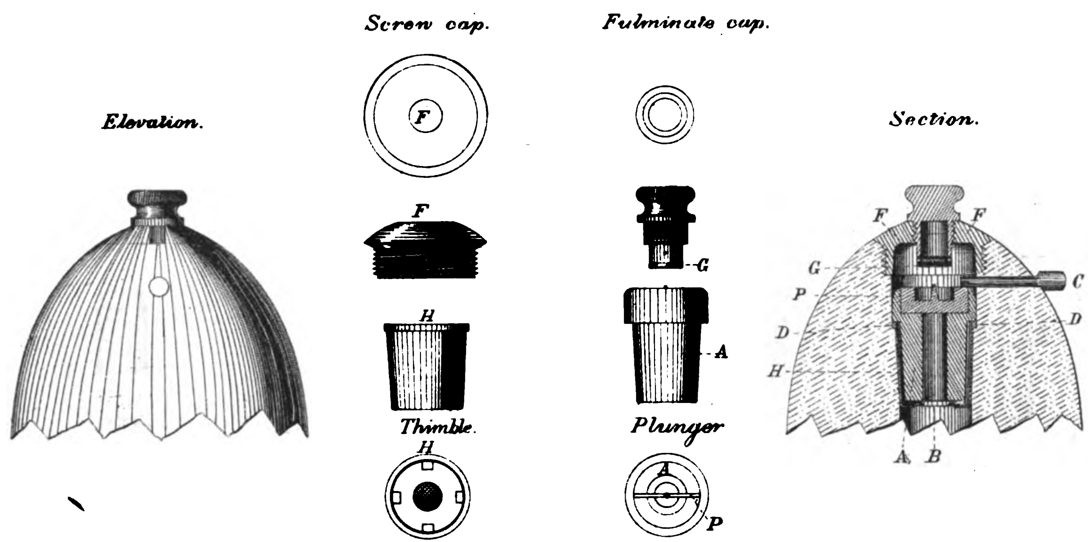
Cap't of Ordnance
Recorder.

GERMAN PERCUSSION FUSE.



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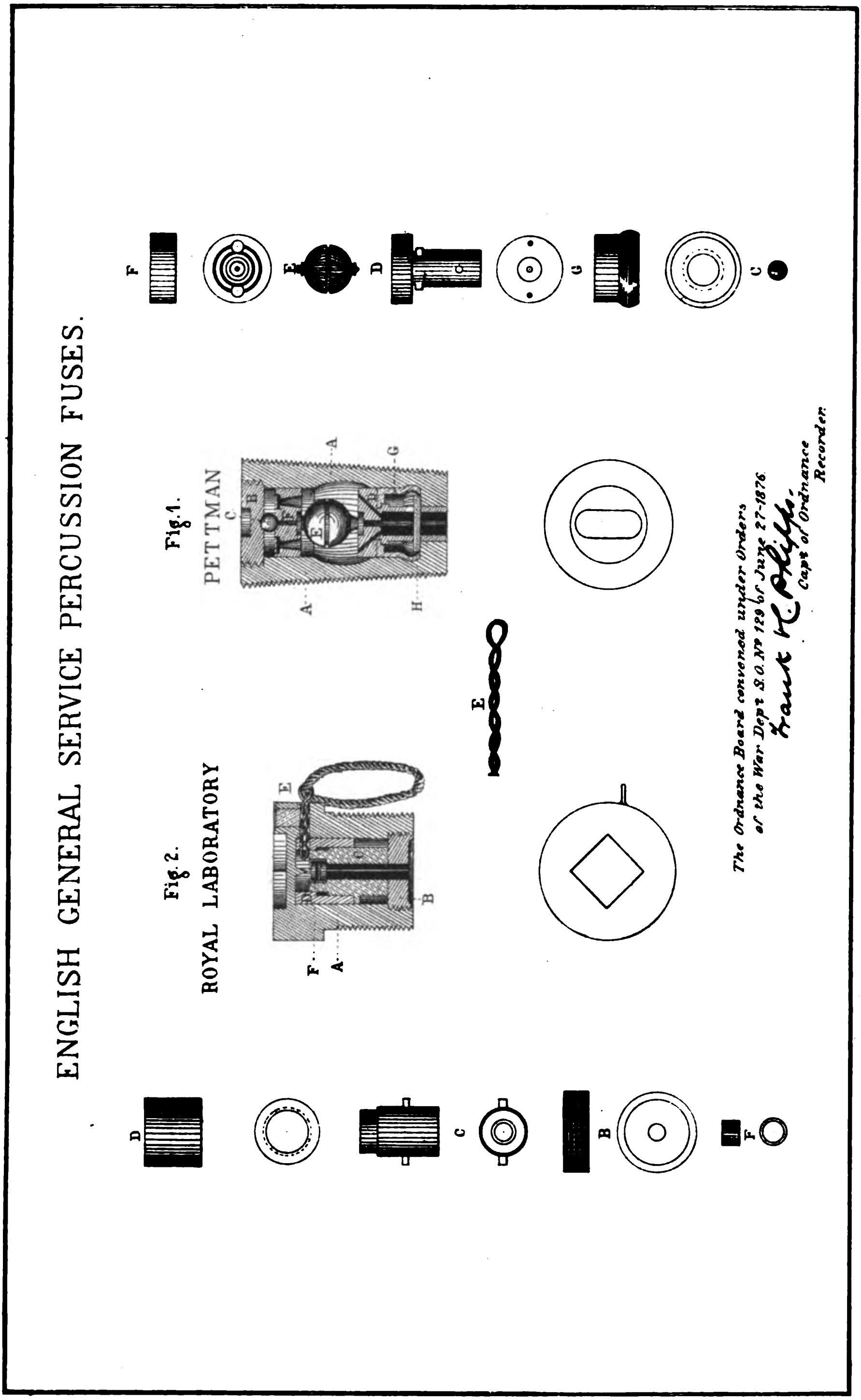
ENGLISH GENERAL SERVICE PERCUSSION FUSES.
Fig. 1.
PETTMAN
Fig. 2.
ROYAL LABORATORY
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LISSBERGER'S FUSES.

Fig. 2.
TIME

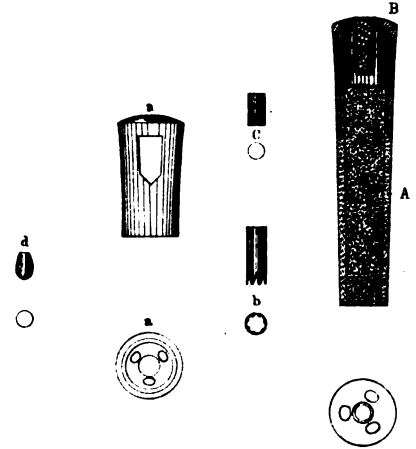
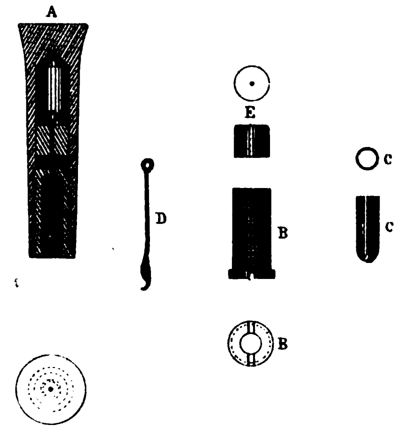


Fig. 1.
PERCUSSION



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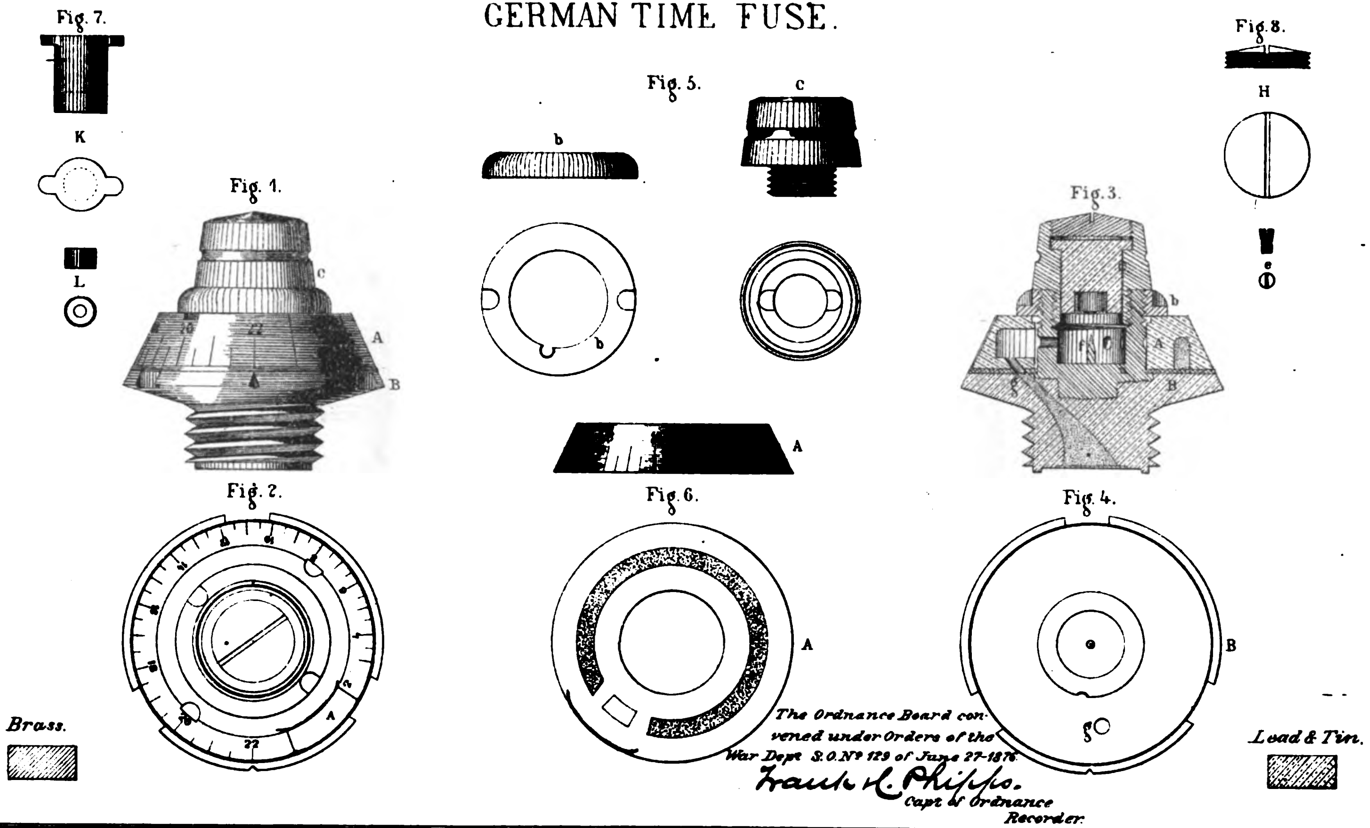
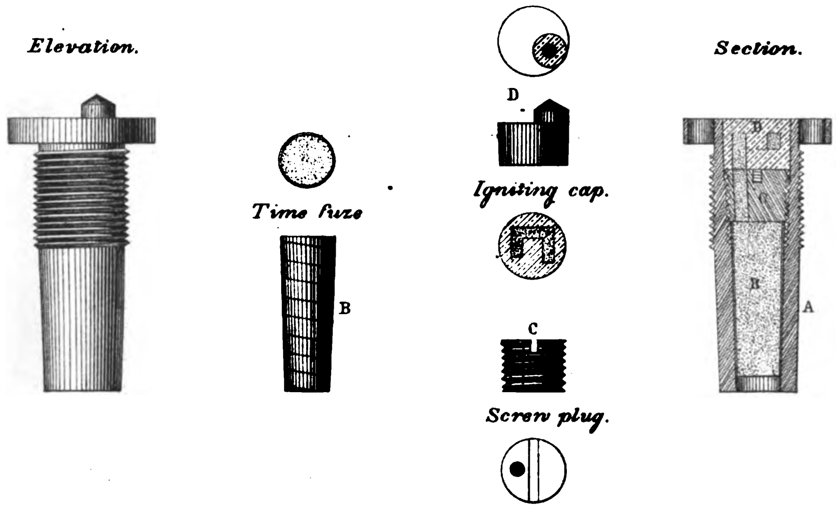
GERMAN TIME FUSE.



M^c INTYRE'S TIME FUSE REAR.



Lead.

Brass

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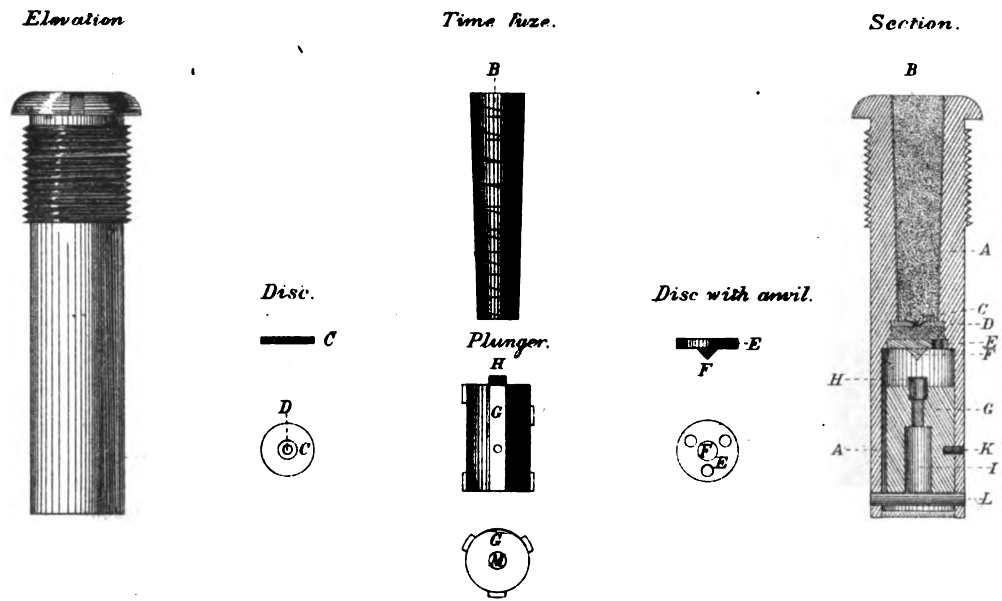
GILL'S COMBINATION FUSE Nº 1.



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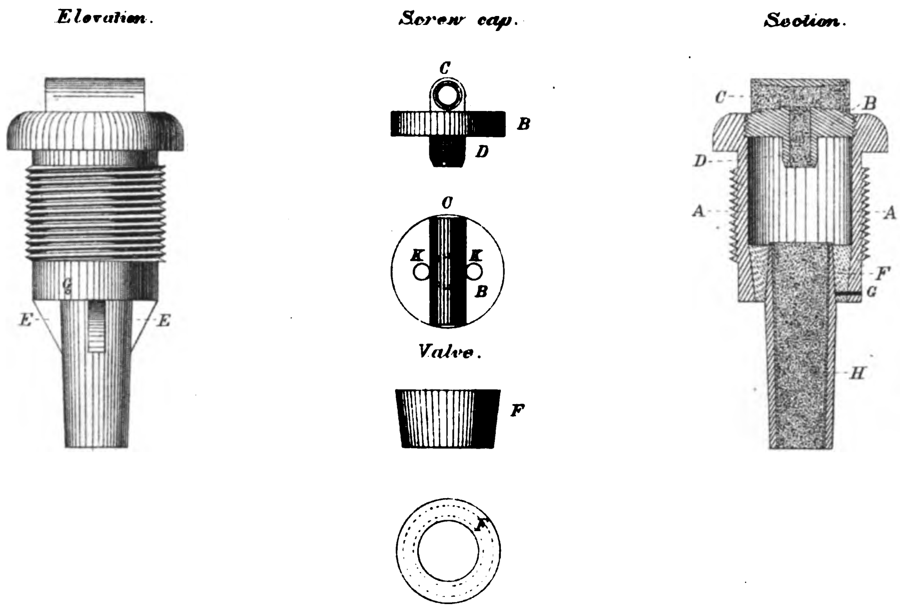
GILL'S COMBINATION FUSE No. 2.



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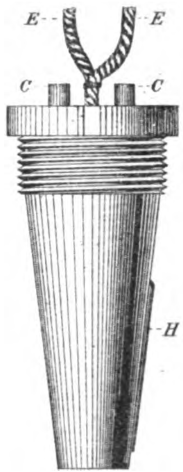
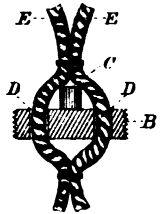
O'REILLY'S COMBINATION FUSE.

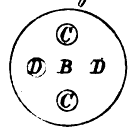
Elevation.

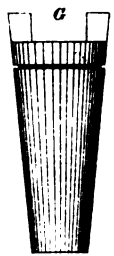


Screw cap

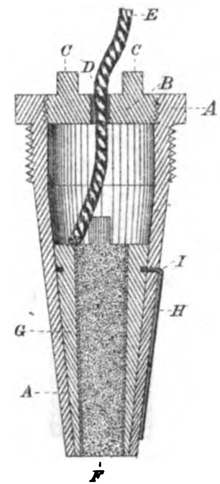


Plunger.





Section.



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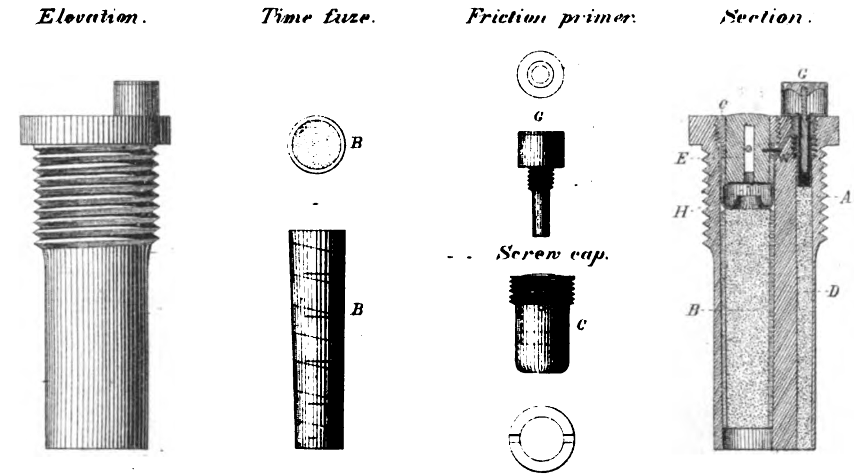
THOMPSON'S COMBINATION FUSE.



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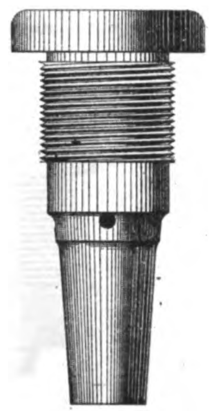
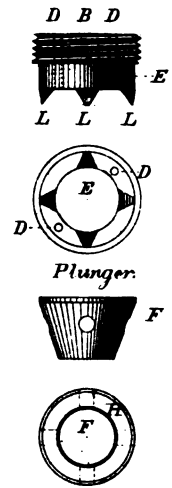
WARE'S COMBINATION FUSE No 1.

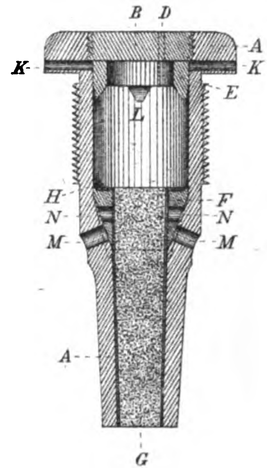
Elevation.



Cap and igniter.



Section.



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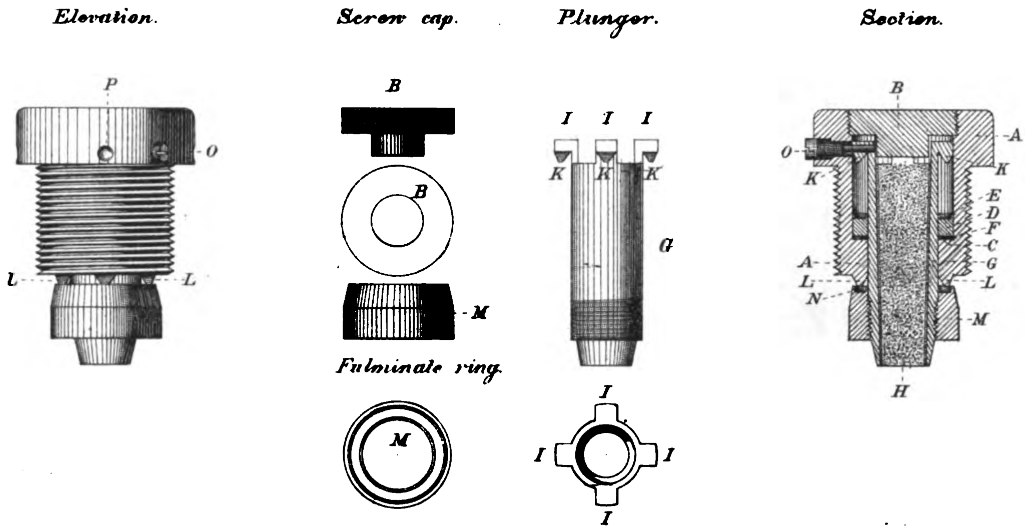
WARE'S COMBINATION FUSE N° 2.



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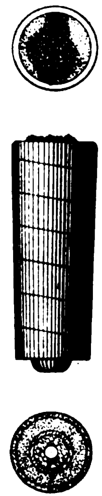
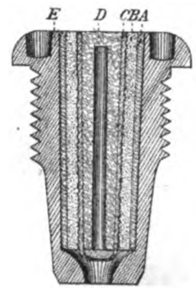
TREADWELL'S COMBINATION FUSE.

Time fuze.

Elevation.



Section.



Lead.	*Paper.*	*Fuze Metal.*	*Plaster of Paris.*

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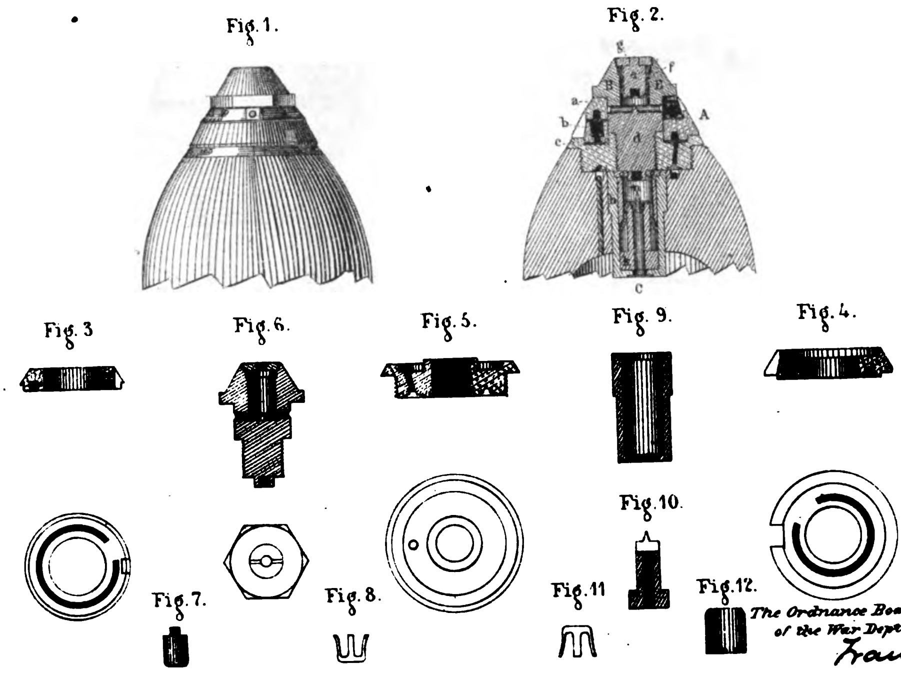
PLATE XVII.

SWISS COMBINATION FUSE Nº 1.

(RUBEN & FORNEROD.)



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of the War Dept S. O. Nº 129 of June 27-1878.
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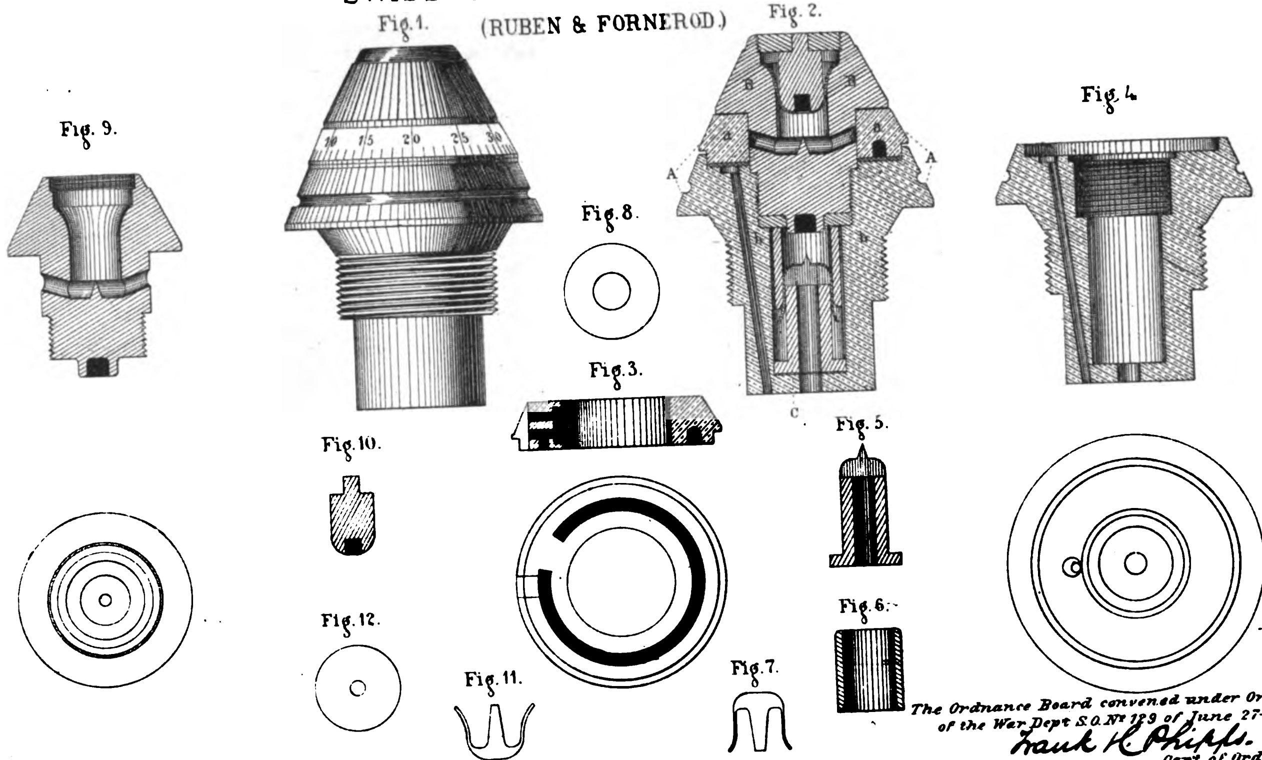
SWISS COMBINATION FUSE No. 2

(RUBEN & FORNEROD.)



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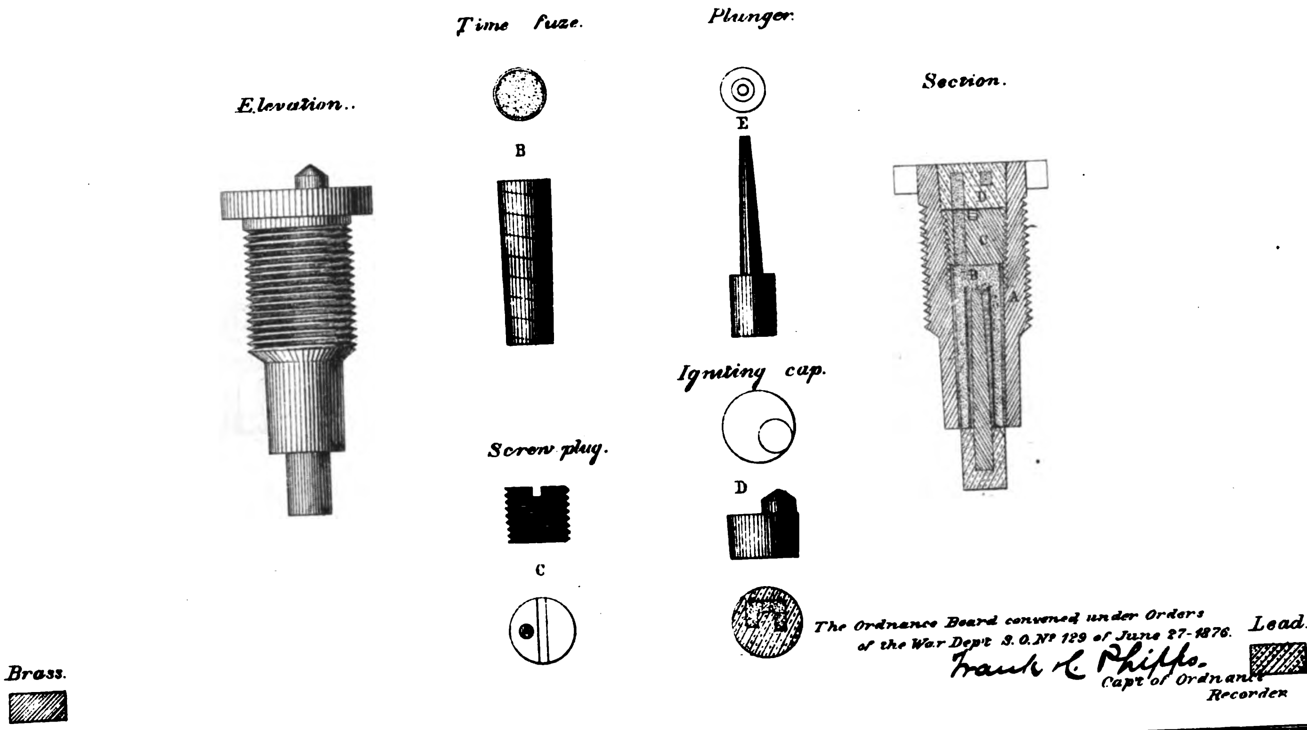
M^c^INTYRE'S COMBINATION FUSE REAR.



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PLUMACHER'S PERCUSSION FUSE.

Fig. 1

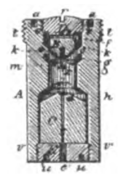

Fig. 6.

Fig. 2.

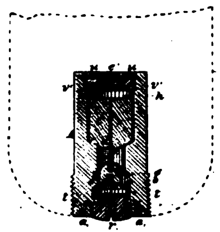

Fig. 5.

Fig. 4.

Fig. 3.

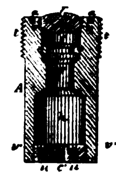

Fig. 7

The Ordnance Board convened under Orders of the War Dep't S.O. No 129 of June 27-1876.

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Capt. of Ordnance
Recorder.

PLATE XXI.

APPENDIX S 3.

TRIAL OF 8-INCH RIFLE—BREECH INSERTION OF TUBE No. 1, MAY 21 TO AUGUST 22, 1878.

DESCRIPTION OF GUN.

A full description and details of construction are given in the report of the constructor of ordnance on this gun. (See page 351.)

CARRIAGE.

The carriage used in the tests so far made was the one known as Altered Carriage No. 3, for full description of which see Report of the Chief of Ordnance for 1877, page 629.

POWDERS.

The powders used were two varieties of the Du Pont's hexagonal, commencing with the (F. U.) E. V., density 1.750, granulation 72—the same that was used in testing the 8″ rifle No. 5—and finishing with F. P. (B.), density 1.785, granulation 67. This latter powder was originally intended for the 12″.25 rifle, but the (F. U.) E. V. not being on hand the F. P. (B) was used, as it was ascertained by a few rounds that it gave about the same pressures and velocities as were obtained in the firings with the 8″ rifle No. 5, with which this rifle was to be compared.

PROJECTILES.

The projectiles were all elongated cast-iron cored shot, with soft metal bases or sabots of the Butler pattern. The shape and general characteristics are the same as the one shown in Plate III, report of the Board on the 8″ rifle No. 1 (Report of the Chief of Ordnance for 1875). The weights used will be found in Tables Nos. 1 and 2.

EXPERIMENTS AND TESTS.

Preliminary to the regular test of this rifle, for endurance, nine rounds were fired with projectiles weighing 181 pounds, and charges of powder varying from 20 to 30 pounds, to note the resulting pressures and velocities and effects on the gun. For record of these firings see Table No. 1. The results so far having proved satisfactory, experiments were commenced for testing the endurance of the gun, using battering charges of 35 pounds.

Five hundred rounds, using 35 pounds of powder, having been fired, a preliminary report of results was made to the Chief of Ordnance, who directed the experiments to continue until 700 rounds in all, with battering charges, had been fired. This programme was completed August 22, 1878. Of the 700 rounds fired, 402 were with (F. U.) E. V. powder, and 298 with the F. P. (B.). (See Table No. 2.)

With the (F. U.) E. V. powder and projectiles averaging in weight 181.21 pounds, an average velocity (at 110 feet from muzzle of gun) of 1,236 feet was obtained with a corresponding pressure of 26,369 pounds

per square inch, while the F. P. (B.) powder, projectiles averaging 182.28 pounds, gave an average velocity of 1,324 feet at same distance, the corresponding pressure being 26,987 pounds.

The mean of all, with both powders, was, for projectiles averaging 181.81 pounds, observed velocity at 110 feet from muzzle of gun 1,272 feet, and a pressure of 26,462 pounds per square inch. This gun has been fired more rapidly than any gun heretofore tested by the Board, as many as 102 rounds having been fired in a day of 7½ hours; besides the firings, the gun was frequently washed out, star-gauged, and impressions of bore taken. Twenty rounds were easily fired in an hour, and on one occasion 10 rounds were fired in the space of a little over 11 minutes. The Boulengé instrument was used in taking the velocities, and the Rodman internal plug for pressures. The average muzzle energy, with all powders and weights of projectiles, using 35-pound charges, was 2,039 foot-tons.

With the 8″ No. 5, using same charges of powder and projectiles averaging 175.74 pounds, a mean energy at muzzle of 2,173 foot-tons was attained, the velocity being 1,340 feet, with a pressure per square inch of 27,019 pounds.

EFFECTS ON THE GUN.

The gun remains in a sound and serviceable condition, with but slight evidences at the bore of erosions or enlargements, the latter being less than in either guns No. 1 or 5. A reference to the tables of enlargements of these guns previously published, and Table No. 3 accompanying, shows as follows:

For the 8″ No. 1, after 776 rounds, an enlargement of 0″.048.
For the 8″ No. 5, after 590 rounds, an enlargement of 0″.054.
For the 8″ B. I., after 709 rounds, an enlargement of 0″.036.

The coiled-weld developments were slight, and showed no sensible increase after they had been first observed. This affords evidence that the shoulder on the tube prevented any forward movement, and thus, the opening of the welds, after the original set had been established.

The record, it will be seen, shows that the mean velocity was, using battering charges and all powders, with projectiles of 182 pounds, 1,272 feet, and that the mean maximum pressure was 26,462 pounds. These results show some deterioration in the powder, as the mean with gun No. 5 was, velocity 1,291 feet, pressure 27,189 pounds.

The mean maximum pressures to which this gun and gun No. 5 were subjected to in their tests, it will be seen, were about the same. The gun under consideration, however, has been fired about 100 more rounds than the No. 5.

EFFECTS ON CARRIAGE.

The carriage, which, previous to its alteration to its present form, had been frequently employed experimentally and at high angles of elevation, has in its present shape been used for about 800 rounds with battering charges and full weights of projectiles. During the course of all the trials only small repairs, such as replacements of bolts &c., had to be made. No injuries requiring extensive overhauling occurred, and the carriage is now in a good serviceable condition. All the parts functioned well, but particularly noticeable was the ease with which the carriage was released, the smoothness with which it ran into battery, and the perfect uniformity and certainty in the action of the lever-catches.

CONCLUSIONS.

The Board finds that the gun, after being fired 700 rounds with battering charges, remains in a sound and serviceable condition, the erosions and development of coil-welds being normal, and the enlargements less than in guns Nos. 1 and 5.

From a consideration of the above facts, the Board feels perfectly satisfied with the endurance of the gun, and believes that the *special plan* of breech insertion employed in its construction is superior in strength to the present plan of muzzle insertion. Also that the facilities it introduces for the employment of shoulders to prevent any accidental blowing out of the tube likely to arise from the common defect of imperfect welding, gives it an important advantage over the present plan of conversion (muzzle insertion).

The cost of this plan of construction will satisfactorily compare with the plan now used.

From these views and facts, the Board feels justified in recommending, in future conversions of our smooth-bore guns, that the breech-insertion plan be employed.

TABLE No. 1.—*Record of firings with the 8-inch experimental rifle, B. I. No. 1, at Sandy Hook, May 21, 1878.*

Description of gun.	Date.	Number of round.	Charge. Kind of powder.	Charge. Cartridge. Weight.	Charge. Cartridge. Height.	Charge. Cartridge. Diameter.
Gun No. 1, B. I.				*Lbs.*	*In.*	*In.*
A rifle converted from a 10″ Rodman cast-iron smooth-bore by lining with a jacketed wrought-iron coiled tube inserted from the rear or breech. Caliber, 8 inches. Total length of gun, $146\frac{1}{16}$ inches. Length of bore, 117.25 inches. Length of rifling, 107.25 inches. Diameter of bore, including grooves, 8.15 inches. Number of grooves and lands, 15. Twist uniform, one turn in 40 feet. Weight of gun, 16,020 pounds.	May 21, 1878	1	Du Pont's hexagonal F. U. E. V. Gran., 72; density, 1.750.	20	12.5	7.15
		2	....do	20	12.5	7.15
		3	....do	25	15.6	7.15
		4	....do	25	15.6	7.15
		5	....do	25	15.6	7.15
		6	....do	30	19.7	7.15
		7	....do	30	19.7	7.15
		8	....do	30	19.7	7.15
		9	....do	30	19.7	7.15

Description of gun.	Projectile. Kind.	Projectile. Weight.	Projectile. Length.	Projectile. Diameter.	Velocities.	Maximum pressure per square inch at surface of bore.	Remarks.
Gun No. 1, B. I.		*Lbs.*	*In.*	*In.*	*Feet.*	*Lbs.*	
	Butler ..	181	20	7.95	1,021	11,500	Distance from muzzle of gun to first wire target, 60 feet; distance between wire targets, 100 feet; distance from muzzle of gun to butt, about 220 feet. All these shots were fired into the butt, and were preliminary to the 700 rounds fired afterward to test the endurance of the gun.
	...do	181	20	7.95	1,020	12,500	
	...do	181	20	7.95	1,084	15,000	
	...do	181	20	7.95	1,102	17,500	
	...do	181	20	7.95	1,076	13,000	
	...do	181	20	7.95	1,179	21,500	
	...do	181	20	7.95	1,176	23,500	
	...do	181	20	7.95	1,192	22,000	
	...do	181	20	7.95	1,208	25,000	

The Ordnance Board convened under orders of the War Department, Special Orders No. 129, of June 27, 1876.

TABLE NO. 2.—*Record of firings for endurance with the 8-inch experimental rifle, B. I. No. 1, at Sandy Hook, from May 21, to August 22, 1878.*

[*Description of gun.*—Gun No. 1, B. I. A rifle converted from a 10-inch Rodman cast-iron smooth-bore, by lining with a jacketed wrought-iron coiled tube inserted from the rear or breech. Caliber, 8 inches. Total length of gun, 146$\frac{1}{16}$ inches. Length of bore, 117.25 inches. Length of rifling, 107.25 inches. Diameter of bore, including grooves, 8.15 inches. Number of grooves and lands, 15. Twist uniform, one turn in 40 feet. Weight of gun, 16,020 pounds.]

Date.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 110 feet from the muzzle of the gun as recorded by Le Boulengé's chronograph.	Velocities at the muzzle.	Energy of projectile.		Gas pressure per square inch of surface of bore, as taken with Rodman's internal pressure gauge.	Remarks.
		Kind of powder.	Cartridge.			Kind.	Weight.	Length.	Diameter.			Total at the muzzle.	Per inch of shot's circumference.		
			Weight.	Height.	Diameter.							$\frac{P.V^2}{2g.2240}$	$\frac{P.V^2}{4g.2240\pi R}$		
			Lbs	*In.*	*In.*		*Lbs.*	*In.*	*In.*	*Feet.*	*Feet.*	*Foot-tons.*	*Foot-tons.*	*Lbs.*	
June 27, and July 6, 1878.	2	Du Pont's hexagonal, F. U. E. V. Density 1.750, gran. 72.	35	22	7.15	Butler.	175	20	7.95	(*)	......	....	....	(*)	Distance of the first wire target from muzzle of the gun, 60 feet; distance between first and second targets, 100 feet. The gun was mounted on experimental carriage No. 3. All shots except 461″ and 510″ were fired into sand butt; these two were fired to sea at an elevation of 10°. Time of flight, 14″. Average velocity with F. U. E. V. powder, 35 pounds, projectile 181.21 pounds, was 1,236 feet; corresponding pressure, 26,369 pounds, with F. P. B. powder; velocity, 1,324 feet; pressure, 26,987 pounds; average weight of projectile, 182.28 pounds. The mean of all with both powders, using 35-pound charges, was 1,272 feet velocity and 26,462 pounds pressure; average weight of projectile, 181.81 pounds.
June 27, and July 6, 1878.	4	....do	35	22	7.15	..do ...	177	20	7.95	1,269	1,276	1,998	79.99	26,750	
June 27, and July 6, 1878	3	....do	35	22	7.15	..do ...	178	20	7.95	(*)	......	....	....	(*)	
July 27, 28, 1878	3	....do	35	22	7.15	..do ...	179	20	7.95	(*)	......	....	....	(*)	
June 27, 28, and July 6, 24, 25, 1878.	107	....do	35	22	7.15	..do ...	180	20	7.95	1,231	1,237	1,907	76.43	26,778	
May 21, June 27, 28, 29, and July 5, 6, 1878.	70	....do	35	22	7.15	..do ...	181	20	7.95	1,242	1,249	1,957	78.34	25,944	
May 23, 24, 25, June 27, 28, 29, and July 6, 1878.	112	....do	35	22	7.15	..do ...	182	20	7.95	1,233	1,240	1,939	77.63	25,682	
May 24, 25, June 27, 28, 29, and July 6, 1878.	89	....do	35	22	7.15	..do ...	183	20	7.95	1,236	1,243	1,960	78.47	26,722	
June 29, 1878.............	2	....do	35	22	7.15	..do ...	184	20	7.95	(*)	......	....	....	(*)	
June 27, 28, 29, 1878	10	....do	35	22	7.15	..do ...	185	20	7.95	1,275	1,282	2,107	84.36	26,000	
July 25, and August 16, 21, 1878.	5	Du Pont's hexagonal, F. P. B. Density 1.785, gran. 67.	35	22	7.15	..do ...	175	20	7.95	(*)	......	....	....	(*)	
July 25, and August 15, 21, 1878.	6	....do	35	22	7.15	..do ...	177	20	7.95	(*)	......	....	....	(*)	
July 25, 26, and August 15, 16, 21, 1878.	5	....do	35	22	7.15	..do ...	178	20	7.95	1,188	1,194	1,759	70.43	20,000	June 27.—Fired 101 rounds, washing out, examining, and star gauging bore 5 times, impressions taken twice, all in about 7½ hours.
August 16, 1878	2	....do	35	22	7.15	..do ...	179	20	7.95	(*)	......	....	....	(*)	
July 25, 26, and August 15, 16, 21, 1878.	121	....do	35	22	7.15	..do ...	180	20	7.95	1,330	1,337	2,230	89.29	26,714	

July 25, 26, and August 15, 16, 22, 1878.	13	....do	35	22	7.15	..do ...	181	20	7.95	(*)	......	....	....	(*)	July 25.—Fired 102 rounds, washing out, examining, and star gauging bore 5 times, impression taken once. Time 7½ hours. During the firings 10 rounds were fired in a little over 11 minutes.
May 24, July 25, 26, and August 15, 16, 22, 1878.	22	....do	35	22	7.15	..do ...	182	20	7.95	1,310	1,317	2,188	87.60	27,375	
May 24, July 25, and August 15, 16, 22, 1878.	58	....do	35	22	7.15	..do ...	183	20	7.95	1,348	1,355	2,329	93.25	28,758	
May 24, and August 15, 16, 22, 1878.	27	....do	35	22	7.15	..do ...	184	20	7.95	1,315	1,322	2,220	89.24	25,750	
August 15, 16, 17, 22, 1878.	36	....do	35	22	7.15	..do ...	185	20	7.95	1,328	1,335	2,285	91.49	26,500	
August 17, 1878	3	....do	35	22	7.15	..do ...	186	20	7.95	(*)	......	....	....	(*)	
Total...............	700														

* Not taken.

TABLE NO. 2.—*Record of firings for endurance with the 8-inch experimental rifle, B. I. No. 1, at Sandy Hook, from May 21, to August 22, 1878.*

[*Description of gun.*—Gun No. 1, B. I. A rifle converted from a 10-inch Rodman cast-iron smooth-bore, by lining with a jacketed wrought-iron coiled tube inserted from the rear or breech. Caliber, 8 inches. Total length of gun, $146\frac{1}{16}$ inches. Length of bore, 117.25 inches. Length of rifling, 107.25 inches. Diameter of bore, including grooves, 8.15 inches. Number of grooves and lands, 15. Twist uniform, one turn in 40 feet. Weight of gun, 16,020 pounds.]

Date.	Number of shots.	Charge.				Projectile.				Mean observed velocities of the projectile at 110 feet from the muzzle of the gun as recorded by Le Boulengé's chronograph.	Velocities at the muzzle.	Energy of projectile.		Gas pressure per square inch of surface of bore, as taken with Rodman's internal pressure gauge.	Remarks.
		Kind of powder.	Cartridge.			Kind.	Weight.	Length.	Diameter.			Total at the muzzle.	Per inch of shot's circumference.		
			Weight.	Height.	Diameter.							$\frac{P.V^2}{2g.2240}$	$\frac{P.V^2}{4g.2240\pi R}$		
			Lbs	*In.*	*In.*		*Lbs.*	*In.*	*In.*	*Feet.*	*Feet.*	*Foot-tons.*	*Foot-tons.*	*Lbs.*	
June 27, and July 6, 1878.	2	Du Pont's hexagonal, F. U. E. V. Density 1.750, gran. 72.	35	22	7.15	Butler.	175	20	7.95	(*)	......	....	....	(*)	Distance of the first wire target from muzzle of the gun, 60 feet; distance between first and second targets, 100 feet. The gun was mounted on experimental carriage No. 3. All shots except 461″ and 510″ were fired into sand butt; these two were fired to sea at an elevation of 10°. Time of flight, 14″. Average velocity with F. U. E. V. powder, 35 pounds, projectile 181.21 pounds, was 1,236 feet; corresponding pressure, 26,369 pounds, with F. P. B. powder; velocity, 1,324 feet; pressure, 26,987 pounds; average weight of projectile, 182.28 pounds. The mean of all with both powders, using 35-pound charges, was 1,272 feet velocity and 26,462 pounds pressure; average weight of projectile, 181.81 pounds.
June 27, and July 6, 1878.	4	....do	35	22	7.15	..do ...	177	20	7.95	1,269	1,276	1,998	79.99	26,750	
June 27, and July 6, 1878	3	....do	35	22	7.15	..do ...	178	20	7.95	(*)	......	....	....	(*)	
July 27, 28, 1878..........	3	....do	35	22	7.15	..do ...	179	20	7.95	(*)	......	....	....	(*)	
June 27, 28, and July 6, 24, 25, 1878.	107	....do	35	22	7.15	..do ...	180	20	7.95	1,231	1,237	1,907	76.43	26,778	
May 21, June 27, 28, 29, and July 5, 6, 1878.	70	....do	35	22	7.15	..do ...	181	20	7.95	1,242	1,249	1,957	78.34	25,944	
May 23, 24, 25, June 27, 28, 29, and July 6, 1878.	112	....do	35	22	7.15	..do ...	182	20	7.95	1,233	1,240	1,939	77.63	25,682	
May 24, 25, June 27, 28, 29, and July 6, 1878.	89	....do	35	22	7.15	..do ...	183	20	7.95	1,236	1,243	1,960	78.47	26,722	
June 29, 1878..............	2	....do	35	22	7.15	..do ...	184	20	7.95	(*)	......	....	....	(*)	
June 27, 28, 29, 1878	10	....do	35	22	7.15	..do ...	185	20	7.95	1,275	1,282	2,107	84.36	26,000	
July 25, and August 16, 21, 1878.	5	Du Pont's hexagonal, F. P. B. Density 1.785, gran. 67.	35	22	7.15	..do ...	175	20	7.95	(*)	......	....	....	(*)	
July 25, and August 15, 21, 1878.	6	....do	35	22	7.15	..do ...	177	20	7.95	(*)	......	....	....	(*)	
July 25, 26, and August 15, 16, 21, 1878.	5	....do	35	22	7.15	..do ...	178	20	7.95	1,188	1,194	1,759	70.43	20,000	June 27.—Fired 101 rounds, washing out, examining, and star gauging bore 5 times, impressions taken twice, all in about $7\frac{1}{2}$ hours.
August 16, 1878	2	....do	35	22	7.15	..do ...	179	20	7.95	(*)	......	....	....	(*)	
July 25, 26, and August 15, 16, 21, 1878.	121	....do	35	22	7.15	..do ...	180	20	7.95	1,330	1,337	2,230	89.29	26,714	

July 25, 26, and August 15, 16, 22, 1878.	13	....do	35	22	7.15	..do ...	181	20	7.95	(*)	......	....	....	(*)	July 25.—Fired 102 rounds, washing out, examining, and star gauging bore 5 times, impression taken once. Time 7½ hours. During the firings 10 rounds were fired in a little over 11 minutes.
May 24, July 25, 26, and August 15, 16, 22, 1878.	22	....do	35	22	7.15	..do ...	182	20	7.95	1,310	1,317	2,188	87.60	27,375	
May 24, July 25, and August 15, 16, 22, 1878.	58	....do	35	22	7.15	..do ...	183	20	7.95	1,348	1,355	2,329	93.25	28,758	
May 24, and August 15, 16, 22, 1878.	27	....do	35	22	7.15	..do ...	184	20	7.95	1,315	1,322	2,229	89.24	25,750	
August 15, 16, 17, 22, 1878.	36	....do	35	22	7.15	..do ...	185	20	7.95	1,328	1,335	2,285	91.49	26,500	
August 17, 1878	3	....do	35	22	7.15	..do ...	186	20	7.95	(*)	......	....	....	(*)	
Total..............	700														

* Not taken.

TABLE No. 3.—*Table of enlargements of 8-inch experimental rifle No. 1, breech insertion.*

Inches from muzzle.	Original play of tube, inches.	Original diameter of bore, inches.	Enlargements of bore, including "setting up" of tube, after—																
			A total of 5 rounds of charges, from 20 to 25 lbs.	A total of 12 rounds, 3 battering charges.	A total of 24 rounds.	A total of 50 rounds.	A total of 80 rounds.	A total of 100 rounds.	A total of 120 rounds.	A total of 201 rounds.	A total of 281 rounds.	A total of 320 rounds.	A total of 351 rounds.	A total of 400 rounds.	A total of 463 rounds.	A total of 510 rounds.	A total of 571 rounds.	A total of 637 rounds.	A total of 709 rounds.
107	0.002	8.001	No enlargement.	0.001	0.002	0.004	0.015	0.015	0.015	0.016	0.015	0.014	0.014	0.015	0.015	0.015	0.016	0.016	0.017
106	.003	8.001		.001	.002	.004	.016	.016	.017	.016	.016	.015	.015	.016	.016	.016	.016	.017	.017
105	.003	8.001		.001	.002	.004	.016	.016	.016	.016	.016	.015	.015	.016	.017	.017	.016	.017	.017
104	.003	8.000		.002	.003	.005	.017	.017	.017	.017	.017	.016	.016	.018	.017	.017	.018	.018	.018
103	.004	8.000		.001	.002	.005	.017	.017	.017	.017	.017	.016	.016	.017	.017	.017	.018	.018	.018
102	.004	8.000		.001	.002	.004	.016	.016	.017	.017	.016	.016	.016	.017	.017	.017	.018	.018	.018
101	.004	8.000		.001	.002	.004	.016	.016	.017	.017	.016	.016	.016	.017	.017	.017	.018	.018	.018
100	.004	8.000		.001	.002	.004	.016	.017	.017	.017	.016	.016	.016	.016	.017	.017	.018	.017	.018
99	.004	8.000		.001	.002	.004	.016	.016	.016	.016	.016	.016	.016	.015	.017	.017	.018	.017	.019
98	.005	8.000		.001	.002	.004	.016	.016	.017	.016	.016	.016	.016	.016	.017	.017	.019	.018	.019
97	.005	8.000		.001	.002	.005	.017	.017	.017	.017	.016	.017	.016	.017	.017	.017	.019	.019	.020
96	.005	8.000		.002	.002	.005	.018	.018	.017	.017	.017	.017	.016	.018	.019	.019	.021	.021	.022
95	.005	8.000		.002	.003	.005	.019	.019	.017	.018	.018	.018	.018	.020	.020	.020	.023	.024	.025
94	.005	8.000		.002	.003	.005	.019	.019	.019	.019	.019	.020	.019	.022	.024	.024	.026	.029	.027
93	.005	8.000		.002	.003	.005	.020	.020	.019	.019	.020	.020	.019	.022	.023	.023	.025	.028	.029
92	.004	8.000		.002	.003	.005	.020	.020	.019	.020	.021	.020	.020	.023	.024	.024	.026	.029	.030
91	.004	8.000		.003	.004	.005	.020	.020	.019	.020	.020	.020	.020	.023	.024	.024	.026	.030	.031
90	.004	8.000		.003	.004	.005	.021	.021	.020	.020	.020	.020	.020	.022	.023	.023	.028	.031	.034
89	.004	8.000		.003	.004	.005	.021	.021	.020	.020	.020	.020	.020	.022	.023	.023	.028	.030	.036
88	.005	8.000		.003	.004	.005	.020	.020	.019	.019	.020	.021	.019	.024	.022	.022	.025	.030	.033
87	.006	8.000		.003	.004	.005	.019	.019	.018	.018	.018	.018	.018	.020	.020	.020	.025	.028	.027
86	.006	8.000		.003	.004	.005	.018	.018	.018	.018	.017	.017	.017	.019	.018	.018	.021	.024	.025
85	.006	8.000		.003	.003	.005	.018	.018	.017	.016	.017	.017	.017	.018	.018	.018	.020	.022	.024
84	.006	8.000		.002	.003	.005	.018	.018	.016	.016	.015	.017	.017	.018	.017	.017	.022	.024	.029
83	.005	8.000		.002	.003	.005	.018	.018	.016	.016	.016	.017	.016	.018	.017	.017	.020	.021	.024
82	.005	8.001		.001	.002	.004	.017	.017	.016	.015	.015	.015	.015	.017	.015	.015	.019	.018	.019
81	.009	8.001		.002	.002	.004	.017	.017	.015	.015	.015	.015	.015	.017	.015	.016	.016	.017	.019
80	.013	8.003		.000	.001	.002	.014	.014	.013	.013	.013	.014	.013	.014	.013	.014	.014	.0114	.0116
78	....	8.003		.000	.001	.002	.011	.011	.011	.010	.010	.009	.010	.010	.010	.010	.013	.011	.011
76	.005	8.002		.001	.002	.003	.006	.006	.006	.005	.005	.005	.005	.006	.004	.004	.007	.005	.005
74	.006	8.001		.002	.003	.004	.007	.007	.005	.006	.006	.004	.004	.005	.004	.004	.004	.004	.004
72	.005	8.001		.002	.003	.003	.007	.007	.005	.004	.004	.004	.004	.005	.004	.004	.005	.005	.004
70	.005	8.001		.002	.003	.003	.007	.007	.006	.004	.004	.004	.004	.005	.004	.004	.004	.005	.004
68	.005	8.001		.001	.002	.003	.005	.006	.005	.004	.004	.004	.004	.005	.003	.004	.004	.004	.004
66	.007	8.001		.001	.002	.003	.004	.004	.004	.004	.004	.004	.003	.004	.003	.004	.004	.004	.004
64	.008	8.000		.000	.003	.004	.005	.005	.005	.005	.005	.005	.004	.005	.004	.005	.005	.005	.005

62	.006	8.001	No enlargement.	.000	.002	.003	.005	.005	.004	.004	.004	.004	.003	.004	.003	.004	.004	.004	.004
60	.006	8.001		.000	.002	.003	.005	.005	.004	.004	.004	.004	.003	.004	.003	.004	.004	.004	.004
58	.006	8.001		.000	.002	.003	.005	.005	.004	.004	.004	.004	.003	.004	.003	.004	.004	.004	.004
56	.005	8.001		.000	.002	.003	.005	.005	.004	.004	.004	.004	.003	.004	.003	.004	.004	.004	.004
54	.007	8.002		.000	.001	.002	.003	.003	.003	.002	.003	.003	.002	.003	.002	.003	.003	.003	.003
52	.005	8.002		.000	.001	.002	.003	.003	.003	.002	.003	.003	.002	.003	.002	.003	.003	.003	.003
50	.006	8.003		.000	.000	.001	.002	.002	.002	.001	.002	.002	.001	.002	.001	.002	.002	.002	.002
48	.006	8.003		.000	.000	.001	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.002	.002	.002
46	.007	8.003		.000	.000	.001	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.002	.002	.001
44	.007	8.003		.000	.000	.001	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.002	.002	.001
42	.007	8.003		.000	.000	.001	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.001
40	.007	8.003		.000	.000	.001	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.001
38	.006	8.003		.000	.000	.001	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.001
36	.006	8.003		.000	.000	.001	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.001
34	.007	8.003		.000	.000	.001	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.000
32	.005	8.003		.000	.000	.002	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.000
30	.007	8.003		.000	.000	.002	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.000
28	.007	8.003		.000	.000	.002	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.000
26	.007	8.005		.000	.000	.002	.002	.002	.002	.002	.001	.001	.001	.002	.001	.002	.001	.001	.000
24	.007	8.003		.000	.000	.002	.002	.002	.002	.002	.001	.001	.001	.002	.001	.002	.001	.001	.000
22	.008	8.003		.000	.000	.002	.002	.002	.002	.002	.001	.001	.001	.002	.001	.002	.001	.001	.000
20	.009	8.003		.000	.000	.002	.002	.002	.002	.002	.001	.001	.001	.002	.001	.002	.001	.001	.000
18	.010	8.003		.000	.000	.002	.002	.002	.002	.002	.001	.001	.001	.002	.001	.002	.001	.001	.000
16	.010	8.003		.000	.000	.002	.002	.002	.002	.002	.001	.001	.001	.002	.001	.002	.001	.001	.000
14	.010	8.003		.000	.000	.002	.002	.002	.002	.002	.001	.001	.001	.002	.001	.002	.001	.001	.000
12	.010	8.003		.000	.000	.002	.002	.002	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.000
10	.010	8.003		.000	.000	.001	.001	.001	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.000
8	.010	8.003		.000	.000	.001	.001	.001	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.000
6	.010	8.003		.000	.000	.001	.001	.001	.002	.001	.001	.001	.001	.002	.001	.002	.001	.001	.000
4	....	8.003		.000	.000	.001	.001	.001	.002	.001	.000	.000	.000	.002	.001	.002	.000	.000	.000
2	....	8.003		.000	.000	.000	.000	.000	.002	.001	.000	.000	.000	.001	.000	.000	.000	.000	.000
1	....	8.003		.000	.000	.000	.000	.000	.002	.001	.000	.000	.000	.001	.000	.000	.000	.000	.000

APPENDIX S 4.

TRIAL OF 12.25-INCH RIFLE, FEBRUARY AND MARCH, 1878.

(One plate.)

THE GUN.

This rifle consists of a cast-iron casing, lined with an English wrought-iron, coiled-welded tube, inserted from the muzzle. A full description of the gun, with details of construction, will be found in the report of the constructor of ordnance.

CARRIAGE AND PLATFORM.

With the exception of a few modifications, the carriage and platform are the same as those recommended and described by the constructor of ordnance in his report of August 7, 1877, to the Chief of Ordnance. (See Appendix T, page 657, Report of the Chief of Ordnance for 1877.)

The few firings made with the 12″.25 rifle demonstrated the necessity of giving more power to the apparatus for throwing the rear eccentrics, on top carriage, "in gear"; and also to the windlass for drawing the gun "from battery." The first was accomplished by increasing the hand-wheel working-worm in size, from 12″ to 18″; the geared wheel on eccentric axle from $9\frac{1}{2}$″ to $14\frac{1}{2}$″; and diminishing the diameter of worm working in geared wheel from $3\frac{9}{16}$″ to 3″, and the pitch of thread from 1″ to $\frac{3}{4}$ of an inch. These changes permit two men, one at each wheel, to throw rollers "in gear." Increased power was given to the windlass by increasing the large geared wheels on the outside and inside of chassis rails from $17\frac{1}{2}$″ to $25\frac{3}{4}$″. The diameter of the drum, around which the rope coils, was diminished somewhat in diameter. A new piston head in cylinder, having three $\frac{3}{4}$″ holes, was substituted for the old one, which had four $\frac{7}{8}$″ holes. The front transom was increased in size from 1″ to $1\frac{1}{4}$″ and the rubber buffers from 6″ x 6″ to 7″ x 7″.

POWDER.

The powder used was Du Pont's hexagonal F. P., density 1.785, granulation 67; similar in shape but slightly larger in size than the F. U. E. V. powder used in trials of the 8″ rifle No. 1, and described in Report of the Chief of Ordnance for 1875, pages 100 and 101.

PROJECTILES.

The projectiles were elongated cast-iron cored shot, with soft metal sabots of the Butler pattern. These sabots are double-lipped rings of

brass, made of copper and zinc, in the proportion of 75 and 25, and were attached to the bases of projectiles by a screw-thread. For general features and dimensions see Plate 1.

EXPERIMENTS AND TESTS.

The gun arrived at Sandy Hook January 17, 1878, and was, February 7, 1878, ready for firing, on which date two rounds were fired using 50 pounds of powder and projectiles of 581 and 579 pounds weight, complying with programme adopted by the Board December 12, 1877, and approved by the Chief of Ordnance December 18, 1877. On the 8th, 9th, 14th, 15th, and 16th days of February the gun was fired, in all, 12 rounds, with charges of powder increasing from 60 to 100 pounds, and with projectiles, all save one of 632 pounds, of 600 pounds' weight.

On the 25th of February the following programme was adopted by the Board:

> The Board considered a programme for further trial of the 12″ rifle, and it was resolved, That the 12″ should be fired 2 rounds with 650 pound shot and 100 pounds of powder; 2 rounds with 700 pound shot and 100 pounds of powder; 2 rounds with 600 pound shot and 110 pounds of powder; 2 rounds with 650 pound shot and 110 pounds of powder; 2 rounds with 700 pound shot and 110 pounds of powder; 2 rounds with 600 pound shot and 120 pounds of powder; 2 rounds with 650 pound shot and 120 pounds of powder; and 2 rounds with 700 pound shot and 120 pounds of powder; the gun to be washed out, star gauged, carefully examined, and gutta-percha impression of bore taken after each round, the carrying out of the programme depending upon the results of these examinations.

For the first ten rounds following the fourteen above referred to the programme was carried out, but on the 25th and 26th rounds it was deemed best to try 2 rounds with 115 pounds of powder and projectiles of 700 pounds' weight before commencing with the higher charge of 120 pounds. The gun has been fired in all 26 times, for record of which see Table 1.

EFFECTS ON THE GUN.

An examination of the attached table of enlargements (Table No. 2) shows a maximum enlargement, after 26 rounds, of 0″.048, of which 0″.009 is due to the original play between tube and casing. No marked erosions or other imperfections have been developed, save a few coil weld marks.

EFFECTS ON CARRIAGE.

During the course of the firing the carriage worked very satisfactorily. But very few alterations, which have been already referred to, were found necessary.

VELOCITIES AND PRESSURES.

☞ An examination of Table No. 1 will show that with 110 pounds of powder and a projectile of 700 pounds' weight an average velocity at muzzle of 1,403 feet was obtained, with a corresponding mean maximum pressure of 31,750 pounds; with 115 pounds of powder and same weight of shot the velocity was 1,485 feet and pressure 33,500 pounds.

These results are very satisfactory, and compare favorably with those obtained abroad with guns of similar caliber.

REMARKS.

The Board, in submitting the above report of progress, would call attention to the following extract from a communication sent to the Chief of Ordnance, dated March 5, 1878, since which time only 2 rounds have been fired, and with highly satisfactory results:

* * * * * * *

By direction of the Ordnance Board, I have the honor to inclose herewith the records of firings up to date with the experimental 12".25 rifle, with the following remarks on the same:

This record is accompanied by carefully calculated tables (prepared by Captain Phipps) of the results of firings made in foreign countries with guns of the same or approximate calibers in their most recent trials. A preliminary comparison between the respective systems of guns, projectiles, and the qualities of powders used, is thus afforded, and the comparative excellencies of our proposed heavy ordnance and the ordnance abroad, in a ballistic point of view, can be discussed from the data thus collected and laid before us.

The strength and endurance of the system of coiled-welded lining tubes, with cast iron for the exterior of the guns, has so far only been thoroughly tested with a caliber of 8 inches, and only with a system involving muzzle insertion.

The system of application by muzzle insertion of the tube is the same in this case; but the results so far with this higher caliber (of 12".25) are too meager to warrant a discussion as to strength and endurance. It may, however, be stated from the results so far attained, using as we have charges as high as 110 pounds of powder and 700-pound projectiles, that we have a fair promise of success; the tube showing no material evidence of any serious imperfections—the system being regarded tangentially of sufficient strength—and the pressures attained, and the generally favorable results, both with projectiles and powders, removing so far any special apprehension as to the satisfactory prosecution of our contemplated experiments.

Any discussion, however, as to this point would, at present, be premature. The object of this communication is, more particularly, to call the attention of the department to the ballistic properties of the gun as developed by these experiments.

The essential features which contribute to any superiority over others in this respect are length of bore, character of projectile, and powder.

The inclosed table shows as follows regarding the lengths of bores, to wit:

	Inches.
American (12".25)	227
English (12") 25 tons	145
Krupp (12".008)	222.5
Italian (12".6)	252

The length adopted by us, it is believed, will give us all the useful effects which can be attained from this source, and by securing a thorough consumption of maximum charges. This has been practically proved by our present experiments, as the absence of unconsumed grains of powder has been especially marked.

Our powders, it will be seen, also have given marked superiority in velocities and pressures attained, the former rising over those given by corresponding charges in foreign services, and the latter being considerably lower in the majority of cases in which comparisons have been instituted. * * The energies attained, or rather the capacities for work (the gist of the whole subject), are given for different charges and weights of projectiles in the inclosed Table No. 3.

The differences in charges and weights of projectiles in our tests and in those of the European powers do not permit a complete comparison; but sufficient can be seen to show an equal if not a decidedly superior capacity for work in the case of the American experimental rifle. For instance, the English 25-ton gun has given less energy by say 450 foot-tons with 85 pounds of powder and a 600-pound projectile than the American rifle. Krupp, with 88 pounds and 664-pound projectile, has given 1,254 foot-tons less; and the Italian with 110 pounds and 770-pound projectile, has only yielded a little over 400 foot-tons more; *our gun using only 80 pounds of powder and 600-pound weight of shot.* With 110 pounds of powder and a 700-pound projectile, the American rifle yields 9,551 foot-tons, an energy about as great as any gun now known for this charge, and decidedly superior to Krupp's and the Italian (see table) using heavier charges.

With these encouraging results, we have only now to develop a strong and durable system of gun construction, having in our powders and projectiles and our rifling and length of bore, elements which, when combined in a rifle, will enable us to cope, we believe, successfully with the most powerful 12″ guns of the world.

In conclusion, it may be stated, the carriage gives every promise of success in every direction. It has sufficient strength in all its parts and generally functions satisfactorily, in its stability on its platform, its means of checking recoil, for elevating and depressing, &c., and more especially in its important feature of the upper carriage being held in position for loading by its clutches, which latter, in conjunction with the inclined planes and carriage-rollers, renders the operation of surely and promptly running into battery a complete success.

TABLE No. 1.—*Record of firing with 12.25-inch muzzle-loading (experimental) rifle, at Sandy Hook, N. J., from February 7, 1878, to March 15, 1878.*

Date of firing.	Number of rounds.	Powder. Kind, Du Pont, hexagonal.	Powder. Weight.	Projectiles. Kind.	Projectiles. Weight.	Mean observed velocities at 145 feet from the muzzle of the gun, as recorded by Boulengé's instrument.	Velocities at muzzle.	Energy of projectile. Total at muzzle. $\frac{WV^2}{2g\,2240}$	Energy of projectile. Per inch of shot's circumference. $\frac{WV^2}{4g\pi R\,2240}$	Energy of projectile. Per one pound of powder. $\frac{WV^2}{2gp\,2240}$	Gas-pressure per square inch of surface of bore, as taken by Rodman pressure-gauge.	Remarks.
			Lbs.		*Lbs.*		*Feet.*	*Foot-tons.*	*Foot-tons.*	*Foot-lbs.*		
February 7, 1878	2	F. P. (G. H.) Density, 1.785. Gr. 67.	50	Butler	580	1100	1105	4909	128	98.18	10,000	Weight of gun, 40 tons.
February 8, 1878	2	do	60	do	600	1177	1182	5811	151	96.85	12,750	Length of bore, 227 inches.
February 8, 1878	2	do	70	do	600	1282	1287	6889	180	98.41	16,000	
February 9, 14, 15, 1878	4	do	80	do	600	1334	1341	7479	195	93.48	20,500	
February 15, 1878	2	do	90	do	600	1405	1413	8304	217	92.26	24,000	
February 16, 1878	1	do	100	do	600	1453	1460	8866	231	88.66	22,500	
February 16, 1878	1	do	100	do	632	1412	1419	8821	230	88.21	23,500	
March 1, 1878	2	do	100	do	650	1391	1399	8818	230	88.18	25,500	
March 1, 1878	2	F. P. (B) like F. P. (G. H.) Density, 1.785. Gr. 67.	100	do	700	1368	1375	9174	239	91.74	22,000	
March 1, 1878	2	do	110	do	600	1502	1512	9508	248	86.43	26,500	
March 2, 1878	2	do	110	do	650	1426	1434	9265	242	84.22	27,500	
March 2, 1878	2	do	110	do	700	1395	1403	9551	249	86.82	31,750	
March 15, 1878	2	do	115	do	700	1478	1485	10701	279	93	33,500	

TABLE No. 2.—*Table of enlargements*

Inches from muzzle.	Original play of tube.	Original diameter of bore.	Enlargements of bore,												
			1st round.	2d round.	3d round.	4th round.	5th round.	6th round.	7th round.	8th round.	9th round.	10th round.	11th round.	12th round.	13th round.
206	0. 009	12. 235	No enlargement.	No enlargement.	No enlargement.	No enlargement.	0. 010	0. 012	0. 015	0. 017	0. 018	0. 017	0. 018	0. 021	0. 024
205	0. 009	12. 236					. 009	. 012	. 014	. 016	. 017	. 017	. 019	. 022	. 025
204	0. 009	12. 236					. 009	. 012	. 015	. 017	. 018	. 018	. 018	. 023	. 026
203	. 009	12. 236					. 009	. 012	. 015	. 017	. 018	. 018	. 018	. 021	. 026
202	. 008	12. 236					. 009	. 011	. 014	. 017	. 017	. 017	. 018	. 021	. 026
201	. 009	12. 236					. 008	. 011	. 012	. 016	. 017	. 017	. 018	. 021	. 025
200	. 009	12. 236					. 006	. 009	. 011	. 014	. 017	. 017	. 018	. 022	. 025
199	. 009	12. 236					. 004	. 008	. 010	. 013	. 015	. 014	. 017	. 021	. 025
198	. 009	12. 236					. 002	. 007	. 009	. 012	. 013	. 013	. 014	. 020	. 025
197	. 009	12. 236					. 001	. 005	. 008	. 011	. 012	. 012	. 014	. 018	. 022
196	. 008	12. 236					. 001	. 003	. 007	. 009	. 010	. 009	. 011	. 015	. 020
195	. 008	12. 236					. 001	. 003	. 005	. 008	. 009	. 009	. 010	. 014	. 019
194	. 008	12. 236					. 001	. 002	. 005	. 006	. 008	. 008	. 009	. 013	. 017
193	. 008	12. 236					No enlargement.	. 001	. 004	. 006	. 006	. 008	. 009	. 010	. 017
192	. 008	12. 236						. 001	. 002	. 004	. 005	. 005	. 007	. 009	. 014
191	. 007	12. 237						No enlargement.	. 000	. 003	. 002	. 003	. 006	. 008	. 011
190	. 007	12. 237							. 001	. 001	. 002	. 002	. 006	. 006	. 009
189	. 007	12. 237							. 001	. 001	. 001	. 002	. 004	. 005	. 010
188	. 008	12. 237							. 001	. 001	. 001	. 003	. 004	. 006	. 008
187	. 007	12. 237							. 001	. 003	. 003	. 003	. 005	. 005	. 008
186	. 007	12. 239							No enlargement.	. 000	. 000	. 001	. 002	. 002	. 006
185	. 007	12. 239								. 001	— . 001	. 000	. 002	. 002	. 006
184	. 007	12. 239								No enlargement.	— . 001	. 000	. 001	. 001	. 005
183	. 007	12. 238									. 000	. 001	. 002	. 002	. 005
182	. 007	12. 238									. 001	. 001	. 002	. 002	. 005
181	. 007	12. 239									. 000	. 000	. 000	. 001	. 004
180	. 007	12. 239									. 000	. 000	. 000	. 000	. 001
179	. 007	12. 239									— . 002	. 000	. 000	. 000	. 001
178	. 007	12. 239									— . 002	— . 001	— . 001	—. 001	. 000
177	. 007	12. 239									— . 002	— . 002	— . 002	—. 002	. 000
176	. 007	12. 238									— . 001	— . 001	— . 001	—. 001	—. 001
175	. 007	12. 238									. 000	— . 001	— . 001	—. 001	—. 001
174	. 008	12. 238									. 000	— . 001	— . 001	—. 001	. 000
173	. 008	12. 238									. 001	. 000	. 002	. 001	. 002
172	. 008	12. 241									— . 001	— . 001	— . 001	. 000	—. 001
171	. 009	12. 242									. 000	. 000	. 000	. 000	. 001
170	. 008	12. 243									— . 001	— . 001	— . 001	. 001	. 002
158	. 010	12. 245									. 000	. 000	. 000	. 000	......
146	. 010	12. 245									. 000	— . 001	— . 001	. 000	......
134	. 009	12. 245									. 000	......	......	......	......
122	. 009	12. 246									— . 001	......	......	......	......
110	. 009	12. 246									......	......	......	......	......
98	. 012	12. 246									......	......	......	......	......
86	. 011	12. 247									......	......	......	......	......
74	. 012	12. 247									......	......	......	......	......
62	. 012	12. 247									......	......	......	......	......
50	. 011	12. 247									......	......	......	......	......
38	. 011	12. 248									......	......	......	......	......
26	. 012	12. 248									......	......	......	......	......
14	. 012	12. 249									......	......	......	......	......
2	......	12. 250									......	......	......	......	......

of 12".25 experimental rifle No. 1.

including "setting up" of tube, after—

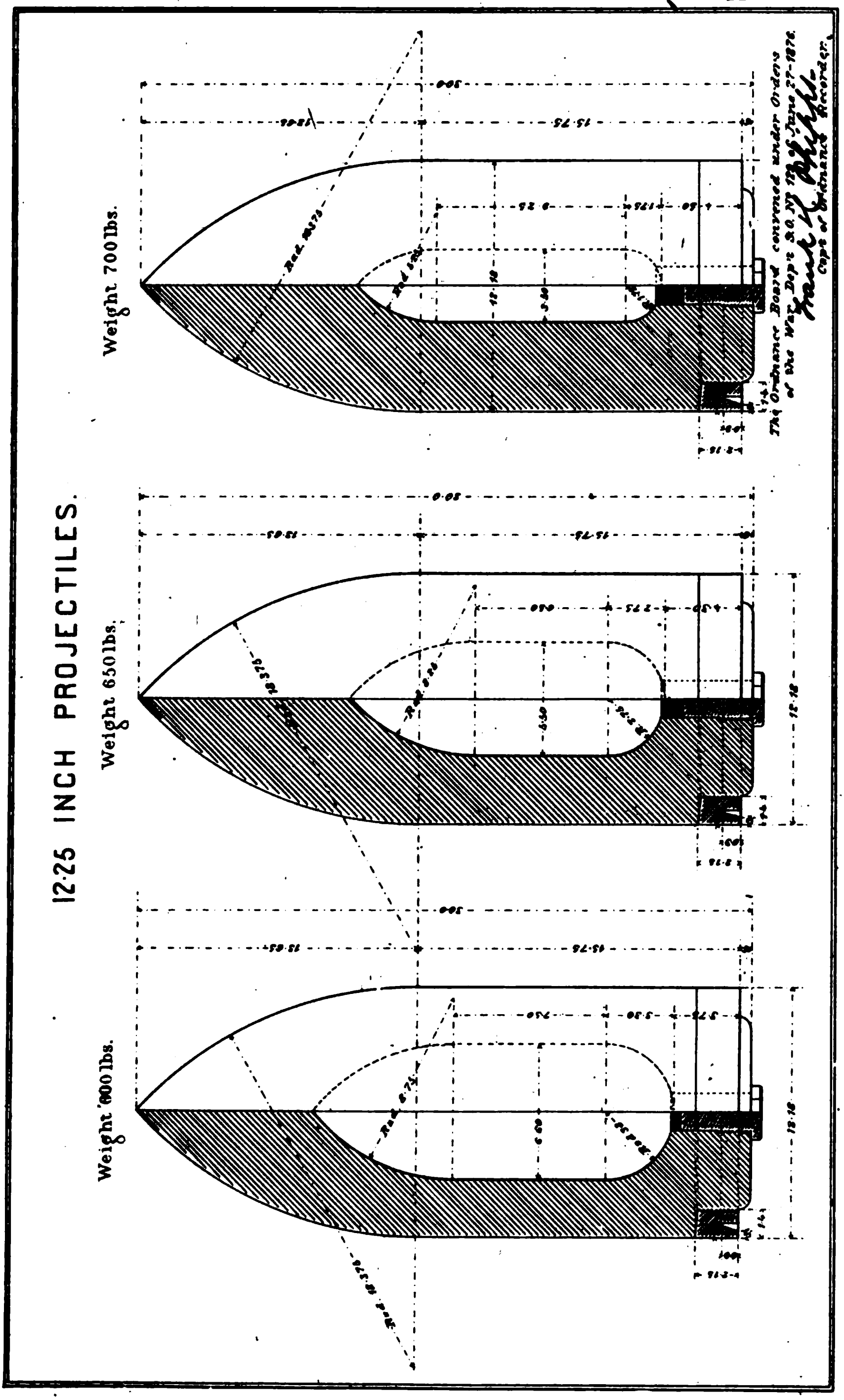
14th round.	15th round.	16th round.	17th round.	18th round.	19th round.	20th round.	21st round.	22d round.	23d round.	24th round.	25th round.	26th round.
0.026	0.028	0.029	0.029	0.030	0.031	0.030	0.030	0.031	0.031	0.033	0.033	0.044
.027	.028	.029	.030	.030	.031	.030	.030	.032	.031	.035	.032	.045
.027	.028	.029	.030	.030	.032	.031	.031	.032	.032	.036	.035	.045
.028	.029	.029	.030	.031	.033	.032	.030	.033	.032	.036	.035	.046
.029	.029	.029	.030	.031	.033	.032	.032	.033	.033	.036	.036	.046
.028	.029	.029	.030	.031	.033	.033	.032	.033	.033	.037	.036	.047
.028	.028	.030	.031	.032	.034	.034	.033	.035	.034	.037	.038	.047
.028	.029	.030	.030	.032	.035	.035	.034	.036	.034	.039	.037	.048
.028	.027	.029	.031	.032	.034	.035	.034	.035	.035	.039	.038	.048
.027	.028	.029	.029	.032	.034	.034	.034	.037	.035	.039	.038	.048
.025	.024	.026	.029	.030	.033	.034	.033	.036	.034	.037	.035	.047
.024	.024	.026	.029	.030	.033	.037	.034	.034	.034	.037	.037	.047
.021	.023	.024	.027	.029	.032	.033	.033	.034	.033	.036	.037	.046
.020	.021	.023	.024	.029	.031	.033	.031	.034	.031	.038	.037	.047
.017	.019	.021	.022	.024	.029	.030	.029	.034	.032	.037	.035	.045
.016	.017	.017	.019	.021	.029	.027	.028	.029	.030	.032	.034	.043
.011	.014	.016	.018	.018	.023	.024	.026	.027	.028	.029	.030	.039
.011	.013	.014	.016	.017	.022	.023	.023	.025	.024	.027	.029	.037
.011	.012	.013	.014	.017	.017	.022	.023	.025	.025	.028	.028	.036
.010	.010	.012	.014	.016	.019	.020	.021	.023	.023	.028	.027	.033
.007	.006	.009	.011	.012	.015	.016	.017	.019	.019	.024	.022	.029
.007	.006	.007	.010	.010	.015	.016	.016	.017	.019	.019	.021	.027
.006	.006	.006	.007	.009	.014	.014	.014	.017	.017	.021	.021	.027
.006	.007	.007	.008	.008	.013	.013	.013	.015	.016	.018	.017	.022
.006	.007	.007	.007	.008	.011	.012	.013	.013	.013	.016	.015	.019
.003	.004	.005	.006	.006	.009	.010	.009	.010	.011	.014	.012	.018
.002	.003	.005	.006	.006	.008	.008	.008	.010	.009	.010	.011	.016
.001	.002	.003	.005	.004	.006	.007	.006	.010	.008	.011	.012	.015
- .001	.001	.001	.004	.003	.006	.006	.006	.008	.006	.008	.006	.011
- .001	.000	.001	.001	.001	.006	.006	.004	.006	.006	.006	.006	.008
.000	.001	.002	.002	.002	.006	.006	.004	.007	.007	.007	.007	.009
.000	.002	.002	.003	.005	.007	.007	.007	.007	.008	.011	.008	.015
.001	.002	.003	.004	.006	.007	.009	.008	.007	.012	.014	.012	.016
.002	.003	.006	.006	.007	.008	.010	.010	.011	.013	.013	.012	.016
.001	.003	.003	.004	.004	.007	.008	.008	.008	.009	.011	.008	.013
.002	.003	.003	.003	.003	.006	.007	.006	.008	.009	.011	.008	.012
.002	.002	.002	.002	.002	.006	.007	.006	.008	.007	.008	.007	.010
....	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.002
....	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	— .001	.000
....	.000	.000	.000	.001	.001	.003	.000	.000	.001	.002	.000	.000
....	— .001	— .001	.000	.000	.000	.002	— .001	— .001	— .001	— .001	— .002	— .001
....	— .001	— .001	.000	.000	.000	.002	— .001	— .001	— .001	— .001	— .001	— .001
....	....	....	....	.000	.000	.002	....	....	....	....	— .001	— .001
....	....	....	....	— .001	.001	.000	....	....	....	....	— .002	— .001
....	....	....	....	....	....	....	....	....	....	....	— .001	.001
....	....	....	....	....	....	....	....	....	....	....	— .002	.000
....	....	....	....	....	....	....	....	....	....	....	— .001	.001
....	....	....	....	....	....	....	....	....	....	....	— .002	.000
....	....	....	....	....	....	....	....	....	....	....	.000	.002
....	....	....	....	....	....	....	....	....	....	....	— .001	.001
....	....	....	....	....	....	....	....	....	....	....	.000	.000

TABLE No. 3.—*Comparative table of fire.*

Kind of gun.	Caliber.	Weight of gun.	Length of bore.	Kind of powder.	Charge of powder.	Weight of shot.	Muzzle velocity.	Pressure per square inch.	Energy of the projectile. Muzzle.	Energy of the projectile. Per inch of shot's circumference.	Energy of the projectile. Per one pound of powder.	Remarks.
	Inches.	*Tons.*	*Inches.*		*Lbs.*	*Lbs.*	*Feet.*	*Lbs.*	*Foot-tons.*	*Foot-tons.*	*Foot-tons.*	
English rifled, muzzle-loading	12	25	145	P	85	600	1, 300	....	7, 030	188	82. 7	
Do	12	35	162½	P	110	700	1, 300	....	8, 200	217	74. 54	
Do	12	35	162½	P	120	700	1, 315	....	8, 404	223	70	
English rifled, muzzle-loading, lengthened.	12	38	198	P	110	700	1, 441	55, 552	10, 076	267	91. 6	
Do	12	38	198	Prismatic	110	700	1, 438	60, 704	10, 034	266	91. 2	
Do	12	38	198	Hall & Son, C	110	700	1, 464	60, 928	10, 448	277	95	
Do	12	38	198	1.25 inches	120	700	1, 435	56, 448	9, 992	265	83. 2	1874.
Do	12	38	198	2.inches	130	700	1, 381	37, 184	9, 254	246	71. 1	
Do	12	38	198	......do	140	700	1, 409	49, 952	9, 634	256	68. 8	
Do	12	38	198	1.7 inches	140	800	1, 313	46, 816	9, 560	254	68. 2	
English rifled, muzzle-loading	12. 5	38	198	P^2	130	800	1, 425	....	11, 263	287	86. 63	
Krupp rifled, breech-loading, 30½ centimeters.	12	36	222½	Prismatic. Density, 1.70–1.76.	88	664	1, 163	18, 620	6, 225	165	70. 74	Average of 5 rounds, August, 1872.
Do	12	36	222½	......do	110	664	1, 329	29, 106	8, 129	215	73. 9	Average of 5 rounds, August, 1872.
Do	12	36	222½	......do	132	666	1, 501	29, 238	10, 401	275	78. 8	Average of 10 rounds, February, 1873.
Do	12	36	222½	......do	143	664	1, 517	42, 424	10, 592	281	74	Average of 5 rounds, August, 1872.
Italian rifled, breech-loading, 32 centimeters.	12. 6	37	252	Density, 1.789	110	770	1, 220	19, 845	7, 944	200	72. 21	
Do	12. 6	37	252	......do	121	770	1, 308	25, 358	9, 132	205	75. 47	September 21, 1874.
Do	12. 6	37	252	......do	132	770	1, 365	35, 427	9, 945	251	75. 34	
Do	12. 6	37	252	"Progressive"	150	770	1, 411	22, 329	10, 627	268	70. 84	
Do	12. 6	37	252	......do	154	770	1, 468	25, 210	11, 502	290	74. 68	1876.
Do	12. 6	37	252	......do	158	770	1, 492	28, 253	11, 866	299	74. 97	
Do	12. 6	37	252	G. Density, 1.778; height of grain, .492125; side of base, .70866; gran., 63.	150	770	1, 384	27, 342	10, 224	258	68. 16	G & K., 1875.
Do	12. 6	37	252	K. Similar to G	150	770	1, 389	29, 841	10, 298	260	68. 65	Wedge-shaped rifling. Average of 9 rounds.
Do	12. 6	37	252	......do	150	770	1, 420	28, 224	10, 763	271	71. 75	Parallel grooves. Average of 9 rounds.

American rifled, muzzle-loading.	12.25	40	227	Du Pont's hexagonal	50	580	1,105	10,000	4,909	128	98.18	Average, 2 rounds.	Tested February and March, 1878.
Do	12.25	40	227	F P (G H). Density, 1.785	60	600	1,182	12,750	5,811	151	96.85	Average, 2 rounds.	
Do	12.25	40	227	......do	70	600	1,287	16,000	6,889	180	98.41	Average, 2 rounds.	
Do	12.25	40	227	......do	80	600	1,341	20,500	7,479	195	93.48	Average, 4 rounds.	
Do	12.25	40	227	......do	90	600	1,413	24,000	8,304	217	92.26	Average, 2 rounds.	
Do	12.25	40	227	......do	100	600	1,460	22,500	8,866	231	88.66	1 round.	
Do	12.25	40	227	......do	100	632	1,419	23,500	8,821	230	88.21	1 round.	
Do	12.25	40	227	......do	100	650	1,399	25,500	8,818	230	88.18	Average, 2 rounds.	
Do	12.25	40	227	F P (B), like F P (G H)	100	700	1,375	22,000	9,174	239	91.74	Average, 2 rounds.	
Do	12.25	40	227	......do	110	600	1,512	26,500	9,508	248	86.43	Average, 2 rounds.	
Do	12.25	40	227	......do	110	650	1,434	27,500	9,265	242	84.22	Average, 2 rounds.	
Do	12.25	40	227	......do	110	700	1,403	31,750	9,551	249	86.82	Average, 2 rounds.	
Do	12.25	40	227	......do	115	700	1,485	33,500	10,701	279	93	Average, 2 rounds.	

PLATE I.



Accompanying Appendix 8a, 1878

APPENDIX S 5.

TRIAL OF 10-INCH RIFLE No. 1, MADE APRIL, 1878.

(One plate.)

This gun was converted by boring up a smooth-bore 13-inch Rodman and inserting, from the muzzle, a coiled wrought-iron lining-tube, on the plan known as system No. 2. For full description of gun and details of construction see report of the Constructor of Ordnance. (See page .)

CARRIAGE.

The carriage used was one adapted to the 15-inch Rodman gun, having two pneumatic buffers. The only alterations were the enlargement of the trunnion-beds, necessitated by the use of eccentric trunnion-rings on gun for correcting muzzle preponderance, and in making the trunnion bed-plates 1½ inches wider on each side to allow for the difference of size of guns between rimbases.

POWDER.

The powder employed was Du Pont's hexagonal F P (B), having a density of 1.785 and granulation of 67. For the average velocities and pressures with the varying charges of from 40 to 80 pounds of powder, see table No. 1 appended.

PROJECTILES.

The projectiles were all of the Butler pattern, and, with the exception of one weighing 365 pounds, of 400 pounds weight. For shape and general dimensions see Plate I.

EXPERIMENTS AND TESTS.

(Table No. 1.)

For the first ten rounds the gun was fired with charges of powder increasing from 40 to 80 pounds (two rounds each of 40, 50, 60, 70 and 80 pounds) to note resulting velocities and pressures, and the effects on the gun. Ten rounds were next fired with 70 pounds of powder. after which 8 rounds with 80 pounds of powder were fired, returning to 70 pounds of powder for the following 5 rounds, making in all 33 rounds fired. The gun was from time to time star-gauged, examined, and impressions of bore taken.

EFFECTS ON THE GUN.

An examination of table No. 2, accompanying, shows a maximum enlargement after 32 rounds of 0''.113, 0''.043 of which is due to the original play in the construction between the tube and casing. The impressions of the bore, which were frequently taken during the firings, show neither sensible erosions nor special or unusual developments of coil-weld marks.

EFFECTS ON CARRIAGE.

The carriage worked satisfactorily throughout, no special developments worthy of note occurring.

RÉSUMÉ OF RESULTS.

The results of the firings so far made are highly satisfactory and promise well for the special system of construction of the tube. In a ballistic point of view, the power of the gun compares favorably with that attained by guns of same caliber in foreign services. Further tests contemplated to be made will settle the question of its endurance.

TABLE No. 2.—*Table of enlargements of 10-inch converted rifle No. 1.*

Inches from muzzle.	Original play of tube.	Original diameter of bore.	Enlargements of bore, including "setting up" of tube, after—														
			1st round.	2d round.	3d round.	4th round.	5th round.	6th round.	7th round.	8th round.	9th round.	10th round.	12th round.	14th round.	16th round.	20th round.	28th round.	32d round.
127	0.063	10.004	0.040	0.080	0.092	0.094	0.102	0.102	0.103	0.104	0.108	0.111	0.113	0.113	0.113	0.113	0.116	0.112
126	.063	.005	.039	.077	.090	.092	.101	.101	.102	.103	.107	.111	.112	.113	.113	.112	.115	.111
125	.061	.004	.039	.074	.089	.092	.100	.101	.101	.101	.107	.111	.111	.114	.113	.113	.116	.111
124	.058	.004	.038	.070	.088	.090	.100	.099	.100	.101	.106	.111	.111	.113	.111	.112	.114	.111
123	.055	.004	.033	.063	.082	.087	.097	.097	.099	.099	.104	.109	.110	.111	.111	.112	.114	.109
122	.049	.005	.031	.058	.080	.082	.095	.095	.097	.098	.103	.108	.109	.110	.111	.110	.113	.108
121	.044	.005	.028	.051	.079	.081	.095	.095	.095	.096	.104	.109	.110	.112	.112	.110	.114	.109
120	.042	.005	.024	.044	.075	.079	.092	.092	.093	.095	.102	.109	.110	.111	.110	.111	.114	.109
119	.041	.005	.020	.038	.071	.075	.090	.091	.092	.094	.102	.111	.109	.111	.111	.111	.114	.109
118	.040	.005	.014	.031	.065	.071	.087	.089	.090	.092	.100	.110	.109	.111	.111	.111	.115	.109
117	.040	.005	.011	.025	.061	.067	.084	.083	.087	.090	.100	.110	.110	.112	.112	.111	.115	.109
116	.041	.005	.008	.020	.057	.062	.080	.081	.084	.089	.099	.111	.112	.113	.112	.112	.115	.110
115	.042	.005	.005	.015	.052	.059	.079	.080	.081	.085	.099	.112	.113	.115	.115	.114	.116	.111
114	.041	.005	.005	.014	.049	.057	.075	.076	.080	.085	.099	.112	.114	.115	.114	.115	.117	.111
113	.043	.005	.004	.011	.044	.053	.075	.075	.079	.085	.100	.112	.113	.114	.113	.114	.116	.113
112	.044	.005	.004	.009	.041	.050	.074	.073	.076	.082	.099	.110	.111	.111	.111	.110	.115	.110
111	.044	.005	.003	.009	.037	.048	.072	.070	.074	.080	.098	.106	.108	.108	.108	.106	.110	.106
110	.042	.005	.003	.008	.032	.044	.069	.068	.070	.079	.095	.103	.104	.104	.103	.104	.107	.105
109	.041	.005	.003	.007	.028	.040	.066	.066	.070	.076	.092	.099	.100	.100	.100	.100	.105	.100
108	.040	.005	.003	.005	.025	.035	.061	.062	.067	.074	.090	.095	.095	.096	.097	.095	.100	.095
107	.038	.005	.002	.005	.021	.032	.059	.059	.064	.070	.091	.092	.093	.094	.094	.094	.096	.092
106	.037	.005	.002	.004	.019	.028	.055	.059	.063	.073	.090	.095	.098	.098	.097	.096	.100	.096
105	.035	.005	.002	.004	.017	.025	.053	.055	.066	.075	.093	.099	.100	.100	.100	.100	.105	.100
104	.033	.006	.001	.002	.013	.020	.045	.048	.059	.072	.088	.094	.094	.095	.095	.094	.098	.094
103	.033	.006	.001	.003	.010	.018	.035	.042	.054	.063	.079	.088	.088	.089	.089	.089	.091	.089
102	.031	.006	.001	.004	.009	.014	.033	.035	.048	.057	.074	.081	.081	.081	.081	.081	.085	.081
101	.030	.006	.001	.003	.008	.011	.028	.030	.040	.050	.069	.077	.079	.079	.079	.081	.081	.075
100	.030	.006	.001	.002	.005	.010	.023	.023	.027	.043	.063	.072	.073	.074	.071	.071	.074	.067
99	.029	.006	.000	.003	.003	.007	.017	.018	.027	.035	.058	.068	.069	.068	.068	.070	.068	.059
98	.030	.006	.000	.002	.004	.002	.005	.007	.012	.032	.044	.053	.055	.056	.056	.057	.060	.056
97	.029	.005	.001	.003	.003	.003	.005	.005	.011	.031	.045	.053	.055	.056	.056	.056	.060	.055
96	.028	.005	.000	.002	.003	.002	.004	.003	.009	.019	.042	.053	.054	.055	.055	.065	.059	.054
95	.028	.005	.000	.000	.003	.002	.003	.003	.009	.016	.030	.049	.050	.052	.051	.051	.056	.051
94	.028	.004	.001	.001	.003	.002	.003	.004	.009	.015	.037	.048	.048	.051	.050	.050	.055	.050
93	.027	.004	.001	.001	.002	.002	.003	.004	.006	.013	.034	.044	.046	.048	.047	.047	.053	.049
92	.027	.004	.001	.001	.002	.002	.004	.003	.006	.012	.030	.040	.042	.046	.036	.043	.051	.047
91	.028	.003	.001	.001	.003	.008	.003	.004	.005	.011	.028	.039	.041	.043	.042	.042	.050	.046
90	.028	.003	.000	.002	.002	.003	.004	.003	.006	.010	.025	.036	.037	.041	.040	.041	.047	.043
89	....	.004	— .001	.001	.001	.002	.003	.002	.005	.008	.032	.030	.033	.036	.036	.036	.045	.041
88	.032	.003	.000	.002	.002	.008	.004	.008	.005	.008	.021	.029	.031	.033	.038	.033	.044	.041

87	....	.003	.000	.002	.002	.002	.004	.003	.004	.007	.017	.025	.080	.081	.081	.081	.042	.039
86	.038	.003	.000	.001	.002	.002	.004	.003	.004	.006	.015	.022	.027	.030	.030	.028	.040	.036
85	....	.003	.000	.001	.002	.002	.004	.003	.003	.006	.013	.020	.023	.026	.026	.026	.037	.035
84	.035	.003	.000	.001	.002	.002	.003	.003	.003	.005	.013	.017	.021	.024	.023	.024	.037	.032
83	....	.003	.000	.001	.002	.002	.003	.002	.003	.005	.011	.015	.020	.022	.023	.023	.037	.033
82	.032	.003	.000	.002	.001	.002	.003	.002	.003	.005	.010	.013	.017	.017	.021	.019	.033	.031
81	....	.003	.000	.002	.002	.002	.002	.002	.003	.004	.010	.013	.015	.016	.019	.020	.032	.028
80	.031	.003	.001	.002	.002	.002	.002	.002	.003	.004	.007	.011	.014	.016	.017	.017	.031	.027
78	.030	.003	.000	.001	.002	.002	.002	.002	.003	.004	.007	.010	.011	.013	.015	.015	.026	.023
76	.028	.003	.000	.001	.001	.002	.002	.002	.003	.004	.007	.007	.010	.012	.013	.012	.022	.023
74	.030	.003	.000	.001	.001	.001	.002	.002	.003	.003	.007	.005	.007	.007	.007	.010	.018	.014
72	.027	.003	.000	.000	.001	.001	.002	.002	.003	.002	.002	.003	.006	.006	.011	.008	.015	.012
70	.027	.003	.000	.001	.001	.001	.002	.002	.002	.002	.003	.003	.006	.006	.007	.007	.014	.012
68	.026	.003	.000	.001	.001	.001	.002	.002	.002	.002	.003	.004	.005	.007	.007	.007	.014	.011
66	.026	.003	.000	.001	.001	.001	.002	.002	.002	.002	.003	.004	.005	.006	.007	.007	.013	.011
64	.026	.003	.000	.001	.001	.001	.002	.002	.002	.002	.004	.003	.005	.006	.007	.007	.013	.011
62	.025	.003	.000	.002	.001	.001	.002	.002	.002	.002	.004	.003	.005	.006	.007	.007	.012	.010
60	.024	.003	.000	.002	.001	.001	.002	.002	.002	.002	.003	.003	.004	.006	.007	.007	.011	.009
58	.026	.003	.000	.002	.001	.001	.002	.002	.002	.002	.003	.003	.004	.005	.006	.006	.010	.008
56	.024	.003	.001	.002	.001	.001	.002	.002	.002	.002	.002	.002	.003	.005	.005	.006	.010	.007
54	.024	.003	.001	.002	.002	.001	.002	.002	.002	.002	.002	.002	.003	.005	.005	.006	.010	.007
52	.024	.003	.001	.002	.002	.001	.002	.002	.002	.002	.002	.002	.003	.005	.005	.005	.008	.006
50	.024	.003	.001	.001	.001	.001	.002	.001	.002	.002	.002	.002	.002	.003	.005	.005	.007	.005
48	.024	.003	.001	.001	.001	.001	.002	.001	.002	.002	.002	.002	.002	.003	.005	.004	.007	.005
46	.024	.003	.001	.001	.001	.001	.001	.002	.002	.002	.002	.002	.002	.003	.005	.004	.007	.005
44	.025	.003	.001	.001	.002	.001	.002	.002	.002	.002	.002	.002	.002	.004	.005	.004	.007	.005
42	.025	.003	.001	.002	.001	.001	.002	.002	.002	.002	.002	.003	.002	.004	.005	.004	.007	.004
40	.024	.003	.001	.001	.001	.001	.001	.002	.002	.002	.002	.002	.002	.003	.005	.003	.005	.004
38	.024	.003	.000	.001	.001	.001	.002	.001	.001	.002	.002	.002	.002	.003	.003	.002	.005	.004
36	.024	.003	.000	.001	.001	.001	.002	.001	.001	.002	.002	.002	.001	.002	.003	.002	.004	.003
34	.024	.003	.001	.001	.001	.001	.002	.001	.001	.001	.002	.003	.001	.002	.003	.002	.005	.003
32	.024	.003	.001	.001	.001	.001	.002	.001	.001	.001	.002	.003	.002	.002	.003	.002	.005	.003
30	.024	.003	.001	.002	.002	.002	.002	.001	.002	.001	.002	.003	.002	.003	.004	.002	.005	.004
28	.024	.003	.001	.002	.002	.002	.002	.002	.002	.002	.002	.003	.003	.004	.004	.002	.005	.004
26	.023	.003	.002	.002	.002	.002	.003	.002	.002	.002	.002	.004	.003	.004	.004	.003	.005	.004
24	.024	.004	.001	.001	.001	.001	.002	.001	.001	.001	.002	.003	.002	.004	.004	.003	.004	.003
22	.024	.005	.000	.001	.001	.001	.001	.000	.000	.000	.001	.001	.001	.003	.003	.003	.005	.002
20	.024	.005	.001	.001	.002	.002	.003	.001	.001	.001	.002	.003	.002	.003	.003	.003	.005	.003
18	.025	.005	.001	.002	.002	.003	.004	.002	.002	.002	.002	.004	.002	.003	.003	.003	.005	.003
16	.024	.006	.000	.001	.002	.003	.003	.002	.002	.001	.003	.003	.002	.003	.003	.004	.004	.002
14	.024	.006	.001	.002	.003	.004	.004	.003	.003	.003	.003	.003	.002	.004	.004	.004	.005	.004
12	.024	.007	.001	.001	.003	.002	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.005	.003
10	0.023	.006	.002	.002	.002	.000	.001	.001	.002	.001	.001	.001	.002	.002	.003	.004	.004	.002
8	....	.005	.000	.002	.002	.001	.001	.000	.001	.001	.002	.002	.001	.003	.001	.004	.004	.003
6	....	.004	.000	.001	.001	.001	.002	.000	.001	.002	.003	.003	.002	.003	.003	.004	.003	.003
4	....	.004	.001	.001	.001	.001	.003	.000	.003	.003	.002	.001	.004	.003	.003	.004	.002	.002
2	....	.004	.001	.001	.002	.001	.002	.000	.002	.003	.002	.003	.003	.002	.002	.004	.002	.003
1	....	0.004	0.000	0.001	0.001	0.001	0.002	0.000	0.002	0.004	0.002	0.004	0.004	0.004	0.002	0.004	0.002	0.003

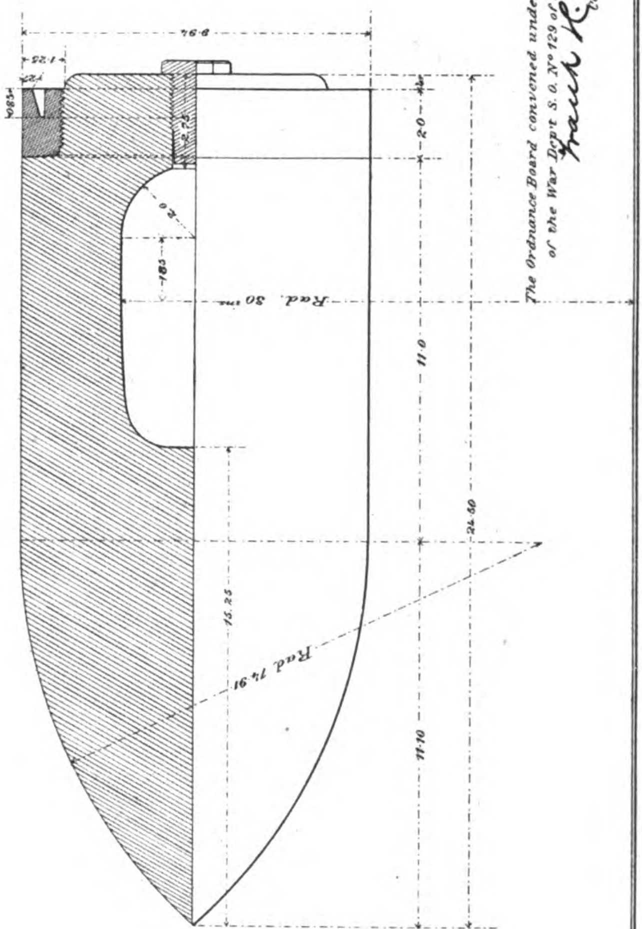
TABLE No. 1.

Record of firing with 10-inch muzzle-loading (experimental) rifle at Sandy Hook, N. J., from April 3 to April 17, 1878.

Date of firing.	Number of round.	Powder.		Projectiles.		Mean observed velocities at 150 feet from the muzzle of the gun, as recorded by Boulengé's instrument.	Velocities at muzzle.	Energy of projectile.			Gas-pressure per square inch of surface of bore, as taken by Rodman pressure-gauge.	Remarks.
		Kind. Du Pont's hexagonal.	Weight.	Kind.	Weight.			Total at muzzle. $\frac{WV^2}{2g\ 2240}$	Per inch of shot's circumference. $\frac{WV^2}{4g\pi R\ 2240}$	Per one pound of powder. $\frac{WV^2}{2gp\ 2240}$		
			Pounds.		*Pounds.*		*Feet.*	*Foot-tons.*	*Foot-tons.*	*Foot-pounds.*		
April 3, 1878	1	F. P. (B.)	40	Butler	365	1, 142	1, 147	3329	106. 6	83. 225	12, 500	Weight of gun, 18 tons.
Do	1	Den. 1.785	40	...do	400	1, 147	1, 152	3680	117. 5	92.	15, 000	Length of bore, 147.22 inches.
Do	2	Gr. 67	50	...do	400	1, 266	1, 272	4486	143. 6	89. 72	16, 750	
April 3 and 4, 1878	2	Gr. 67	60	...do	400	1, 340	1, 347	5031	161. 1	83. 85	20, 500	
April 4, 5, and 17, 1878	17	Gr. 67	70	...do	400	1, 381	1, 389	5349	171. 29	76. 3	22, 622	
April 4 and 5, 1878	10	Gr. 67	80	...do	400	1, 422	1, 430	5670	181. 5	70. 875	23, 833	
	30											

10 INCH PROJECTILE.

Weight 400 lbs.



The Ordnance Board convened under Orders of the War Dep't S. O. No 129 of June 27 - 1876.

Frank H. Phipps
Capt of Ordnance
Recorder.

Accompanying Appendix 8a, 1878

APPENDIX S 6.

TRIAL OF 8-INCH BREECH-LOADING RIFLE, MADE AUGUST, 1878.

(One plate.)

GUN AND CARRIAGE.

The gun and carriage have been fully described by the Constructor of Ordnance (pages 359 and 365).

POWDER AND PROJECTILES.

The powder so far used has been Du Pont's hexagonal F. P. (B.); density, 1.785; granulation, 67. The projectiles were of the Butler pattern, averaging in weight about 185 pounds. They differ from those used in the 8″ muzzle-loading rifle only in the shape of the sabots, the lip of which has a slight flare, to prevent the projectile in loading being pushed beyond its proper seat. For general features and dimensions see plate.

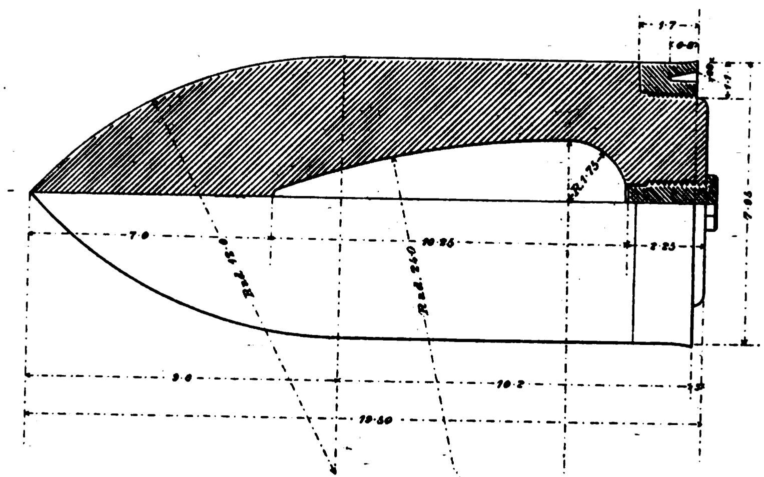
EXPERIMENTS AND TESTS.

The rifle was received at Sandy Hook July 8, and was ready for firing August 1. It has been fired up to date in all 34 rounds, with charges of powder as follows: One with 15 pounds, 2 with 20 pounds, 3 with 25 pounds, 3 with 30 pounds, and 25 with battering-charges of 35 pounds, using in all cases projectiles of about 185 pounds in weight.

The results are normal as to energies and pressures, and the gun remains in a sound and serviceable condition and now awaits the further proof contemplated by the department.

PROJECTILE FOR 8 INCH B. L. RIFLE.

Weight 180 lbs.



The Ordnance Board convened under Orders of the War Dept S. O. No 129 of June 27th 1876.

Frank K. Phipps.
Capt of Ordnance
Recorder.

APPENDIX T.

REPORT OF THE BOARD OF OFFICERS CONVENED IN CONFORMITY WITH THE ACT OF NOVEMBER 21, 1877, TO SELECT A MAGAZINE GUN FOR THE MILITARY SERVICE.

(Twenty-one plates.)

NATIONAL ARMORY,
Springfield, Mass., September 28, 1878.

SIR: I have the honor to forward to your address, by to-day's express the report of the Board on Magazine Guns, convened at National Armory by virtue of General Orders No. 115, Headquarters of the Army, Adjutant-General's Office, Washington, December 18, 1877.

* * * * * * *

Very respectfully, your obedient servant,

J. G. BENTON,
Lieutenant-Colonel of Ordnance,
President of Board.

To the ADJUTANT-GENERAL, U. S. A.,
Washington, D. C.

[First indorsement.]

ADJUTANT-GENERAL'S OFFICE,
Washington, September 30, 1878.

Respectfully referred to the Chief of Ordnance.

E. D. TOWNSEND,
Adjutant-General.

[Second indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, October 1, 1878.

Respectfully submitted to the Secretary of War, with the recommendation that the report and recommendation of the Board on Magazine Guns be approved, and that this department carry out the provision of law by expending at the National Armory $20,000 in the manufacture of the Hotchkiss magazine-gun, No. 19.

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

Approved.

GEO. W. McCRARY,
Secretary of War.

OCTOBER 1, 1878.

REPORT.

NATIONAL ARMORY,
Springfield, Mass., September 23, 1878.

In pursuance of General Orders No. 115, from the headquarters of the Army, dated December 18, 1877, the Board met on the 3d of April, 1878, and has continued in session—with the exception of such adjournments as were authorized by the Secretary of War and necessitated by the delay of inventors—up to the present time, when a compliance with instructions from the Secretary of War, limiting the time for reception of arms, has terminated its duties.

The Board, in the discharge of these duties, has tested all the guns presented uniformly and in the manner that seemed to it best adapted to determine the question of their suitability for the military service, as well as to determine their comparative merits in that respect.

The regulations for the trials adopted by the Board are given in the appendix.

Its experiments to test the liability of accidental explosion of cartridges in the magazine seem to show that there is little probability of such explosion when using the inside-primed service-cartridges, or even with the exterior-primed cartridges direct from the factory, when fabricated and inspected with the care and attention usually given them. With cartridges reprimed in the field or garrison, risks may be introduced which have not come within the scope of the investigations of the board.

From the satisfactory manner in which the Hotchkiss gun, No. 19, has passed these tests, and from its combination of strength, simplicity, and great effectiveness as a single loader, the Board is of the opinion that the Hotchkiss gun, No. 19, is suitable for the military service, and it does, therefore, recommend it as such.

J. G. BENTON,
Lieutenant-Colonel of Ordnance, President of Board.
F. H. PARKER,
Major of Ordnance.
J. P. FARLEY,
Major of Ordnance.

There being no further business before it, the Board adjourned *sine die.*

J. G. BENTON,
Lieutenant-Colonel of Ordnance, President of Board.

JOHN E. GREER,
Captain of Ordnance, Recorder of Board.

DOCKET.

The following magazine-guns were received and entered on the docket:

Number of gun.	Name of gun.	By whom submitted.
No. 1	Franklin	General W. B. Franklin.
No. 2	Ward-Burton	Commanding officer National Armory.
No. 3	Sharps	Sharps Rifle Company.
No. 4	Hunt	C. B. Hunt.
No. 5	Sharps	Sharps Rifle Company.
No. 6	Lewis-Rice	Lewis-Rice & Lewis.
No. 7	Buffington	Major Buffington, U. S. A.
No. 8	Sharps	Sharps Rifle Company.
No. 9	Hotchkiss	Winchester Arms Company.
No. 10	Buffington	Major Buffington, U. S. A.
No. 11	Burton	B. Burton.
No. 12	Hotchkiss	Winchester Arms Company.
No. 13	Winchester repeater	Winchester Arms Company.
No. 14	Lewis-Rice	Lewis-Rice & Lewis.
No. 15	Springfield-Miller	W. H. Miller.
No. 16	Lewis-Rice	Lewis-Rice & Lewis.
No. 17	Remington	E. Remington & Sons.
No. 18	Hotchkiss	Winchester Arms Company.
No. 19	Hotchkiss	Winchester Arms Company.
No. 20	Lewis-Rice	Lewis-Rice & Lewis.
No. 21	Tiesing	Whitney Arms Company.
No. 22	Burgess	Whitney Arms Company.
No. 23	Burgess	Whitney Arms Company.
No. 24	Springfield-Clemmons	G. F. Clemmons.
No. 25	Lee	James Lee.
No. 26	Chaffee	R. S. Chaffee and J. N. Reece.
No. 27	Springfield-Clemmons	G. F. Clemmons.

Proceedings of a Board appointed for the purpose of selecting and recommending a magazine-gun for the military service, should one be found suitable, which convened at the National Armory, Massachusetts, April 3, 1878, pursuant to the following orders:

[General Orders No. 115.]

HEADQUARTERS OF THE ARMY,
ADJUTANT-GENERAL'S OFFICE,
Washington, December 18, 1877.

The following order is received from the War Department:

The act making appropriations for the support of the Army for the year ending June 30, 1878, and for other purposes, approved November 21, 1877, contains this provision:

"For manufacture of arms at the National Armory, one hundred thousand dollars; and should a board of ordnance officers, appointed by the Secretary of War, recommend a magazine-gun for the military service, the Secretary of War is authorized to expend not more than twenty thousand dollars of this amount in its manufacture."

In conformity with this law, a Board will assemble at the National Armory, Springfield, Mass., on the 3d day of April, 1878, to consider and recommend a magazine-gun, should one be found suitable, for the military service.

Detail for the board.—Lieut. Col. J. G. Benton, Ordnance Department.

Maj. F. H. Parker, Ordnance Department.

Capt. J. H. Rollins, Ordnance Department.

First Lieut. J. E. Greer, Ordnance Department, will report to the President of the Board for duty as recorder.

All persons interested in magazine-guns are invited to submit samples and appear in person, under such rules as may be adopted by the Board. The arms submitted must be calibre .45, and use the United States service cartridge.

Any information required by those interested may be obtained of Colonel Benton, National Armory, Springfield, Mass.

The Chief of Ordnance will supply such information and offer such facilities to the Board as may be necessary in the prosecution of its labors.

By command of General Sherman.

E. D. TOWNSEND,
Adjutant-General.

Official.
E. D. TOWNSEND,
Adjutant-General.

[Special Orders No. 50.]

HEADQUARTERS OF THE ARMY,
ADJUTANT-GENERAL'S OFFICE,
Washington, March 8, 1878.

[Extract.]

* * * * * * *

13. By direction of the Secretary of War, Maj. J. P. Farley, Ordnance Department, is detailed as a member of the Board appointed to assemble at the National Armory, Springfield, Mass., on the 3d day of April, 1878, by General Orders No. 115, December 18, 1877, from this office, in place of Capt. J. H. Rollins, Ordnance Department, hereby relieved.

* * * * * * *

By command of General Sherman.

E. D. TOWNSEND,
Adjutant-General.

Official:
L. H. PELOUZE,
Assistant Adjutant-General.

OFFICE OF THE BOARD ON MAGAZINE-GUNS,
National Armory, Springfield, Mass., April 3, 1878.

The Board met pursuant to the foregoing orders.

Present: All the members and the recorder.

The Board, after discussion, adopted the following rules and tests for the trial of all magazine-guns submitted under the order:

The piece to be first fired ten rounds by the exhibitor, as a test of safety; the same firing to be also a test of rapidity by one familiar with the arm. The time to be noted in the record:

The firing to be then continued according to the rules annexed, by an employé of the armory, or soldier detailed by the War Department.

The service-cartridge to be used in all cases.

No persons will be admitted to the firing-ground but the agents or exhibitors of the gun immediately under trial, and such other persons as may be specially invited by the Board.

The handling of guns by their representatives at *any* time after the preliminary test for safety is *forbidden.*

Any arm which has been submitted to the Board and entered upon the record, shall remain in the hands of the Board for such time as may be necessary to make drawings explanatory of its mechanism.

If a gun become disabled or unserviceable, all further tests will be discontinued, and the proprietor informed of the fact. If the gun be altered and resubmitted to the Board, it will be treated as a new gun.

REGULAR TESTS.

Safety test: To be fired ten rounds by the exhibitor or with a lanyard.

I.—RAPIDITY WITH ACCURACY.

The number of shots which, fired in two minutes from the gun—both as a magazine-gun and as a single shooter—strike a target 6 feet by 2 feet at a distance of 100 feet. Any cartridges missing fire in this or other tests to be tried with a prick punch, or opened to ascertain the cause of failure. The test to be begun with the chamber or magazine filled; other cartridges to be disposed at will on a table.

II.—RAPIDITY AT WILL.

The number of shots which can be fired in one minute, irrespective of aim, under the same circumstances as in Test I.

III.—Endurance.

Each gun to be fired 500 continuous rounds without cleaning, using the magazine. The state of the breech mechanism to be examined at the end of every 50 rounds.

IV.—Defective cartridges.

Each gun to be fired once with each of the following defective cartridges: 1. Cross-filed on head to nearly the thickness of the metal. 2. Cut at intervals around the rim. 3. With a longitudinal cut the whole length of the cartridge, from the rim up. A fresh piece of white paper, marked with the number of the gun, being laid over the breech to observe the escape of gas, if any occur.

V.—Dust.

The piece to be exposed in the box prepared for that purpose to a blast of fine sand-dust for 2 minutes; to be removed, fired 20 rounds, replaced for 2 minutes, removed and fired 20 rounds more.

VI.—Rust.

The breech mechanism and receiver to be cleansed of grease, and the chamber of the barrel greased and plugged, the butt of the gun to be inserted to the height of the chamber in a solution of sal-ammoniac for 10 minutes, exposed for two days to the open air standing in a rack, and then fired 20 rounds.

VII.—Excessive charges.

To be fired once with 85 grains of powder and one ball of 405 grains of lead; once with 90 grains and one ball, and once with 90 grains and two balls. The piece to be closely examined after each discharge.

SUPPLEMENTARY TESTS.*

1st. To be fired with two defective cartridges, Nos. 1 and 2, and then to be dusted five minutes, the mechanism being in the mouth of the blow-pipe, and closed, the hammer being at half-cock; then to be fired 6 shots, the last two defective Nos. 1 and 2; then without cleaning to be dusted with the breech open, and fired 4 shots. The piece to be freed from dust only by pounding or wiping with the bare hand.

2d. To be rusted for 4 days after immersion as before, and then fired 5 rounds with the service cartridge; then without cleaning to be fired 5 rounds with 120 grains powder and a ball weighing 1,200 grs.; the gun to stand twenty-four hours after firing without cleaning, and then to be thoroughly examined.

3d. Facility of manipulation by members of the Board.

4th. Liability to accidental explosions of cartridges in the magazine.

Additional tests may be made by the Board to clear up doubts raised by previous trials.

Mr. Merwin, of the firm of Merwin, Hulbert & Co., appeared before the Board and expressed a desire to bring before it an Evans gun, cal.

* To be applied only to such arms as have passed through the regular test in a manner satisfactory to the Board.

0''.44, and to have a special report on it preceding the final report of the Board.

Mr. Merwin informed the Board that he had made application to the Chief of Ordnance, U. S. A., to this effect, expressly stating that the gun was cal. 0''.44, using a cartridge containing 50 grains of powder. He presented a letter from the Chief of Ordnance which he stated was in reply to his own letter, in which the Chief suggested that he bring his gun before the Board. On consideration the Board decided that under the terms of the order constituting it, it could not entertain this application without special instructions from proper authority.

There being no further business before it, the Board adjourned to meet at 10 a. m. the 4th instant.

NATIONAL ARMORY, MASS.,
April 4, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Messrs. Richards and Whitney presented a magazine-gun, on behalf of General W. B. Franklin, which was examined and discussed by the Board. The Board then submitted this gun to the regular tests with the results stated in the synopsis.

There being no further business before it, the Board adjourned to meet at 10 a. m. the 5th instant.

NATIONAL ARMORY, MASS.,
April 5, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board, after discussion, decided that the Franklin gun was unserviceable and that, in accordance with the rules adopted, further tests should be discontinued.

Mr. Merwin, of Merwin, Hulbert & Co., withdrew his application of the 3d to have the Evans gun, cal. 0''.44, tested and reported on previous to the final report of the Board. The following letter was received, read, and directed to be placed on the record:

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, April 4, 1878.

The PRESIDENT OF THE BOARD ON MAGAZINE GUNS,
National Armory, Springfield, Mass.:

SIR: The Chief of Ordnance having received the following telegraphic message, viz:

"SPRINGFIELD, MASS., *April* 3, 1878.

"General S. V. BENÉT,
"*Chief of Ordnance, Washington, D. C.:*

"We respectfully ask for an order of trial and special report by the Board now convened at Springfield for Evans gun referred to in our letter of March 21. The Board hesitate about trying a 0''.44 caliber. Awaiting early reply by wire.

"Massasoit House.

"MERWIN, HULBERT & CO."

submitted it to the Secretary of War with this indorsement, viz:

"ORDNANCE OFFICE, WAR DEPARTMENT,
"*April* 4, 1878.

"Respectfully submitted to the Secretary of War, recommending that the Board should treat all guns alike, and no exceptional and special trial and report should be permitted with the Evans or any other guns, because the law contemplates the selection of one for the service.

"A gun of caliber 0".44 need not be thrown out if the trial will prove its merits when using regulation ammunition, and this should be left discretionary with the Board.'

The Chief of Ordnance directs me to inform you that the Secretary has approved the views expressed in the above indorsement, and that they are now given you for your guidance in this and any future cases of like character that may arise.

Respectfully, your obedient servant,

S. C. LYFORD,
Major of Ordnance.

There being no further business before it, the Board adjourned to meet at 10 a. m., the 6th.

NATIONAL ARMORY, MASS.,
April 6, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Letter was received from Mr. Josiah Dupau, asking information as to time of meeting of Board and when it could consider his invention. The Board directed the recorder to notify Mr. Dupau that it was now in session and would examine his arm as soon as presented.

As there were no guns before it for consideration, the Board adjourned to meet at 10 a. m., the 8th.

NATIONAL ARMORY, MASS.,
April 8, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

A letter was received from General Franklin, asking permission to withdraw his gun for alteration, to which the Board assented.

The commanding officer, National Armory, submitted the Ward-Burton magazine-gun referred to in the report of the Board on breech-loading small-arms, of which General Terry, U. S. A., was president. This gun was the property of the United States, having been made at the Armory in 1873, under the direction of General Ward and his agent.

The Board proceeded to the trial of this arm with the result as stated in the synopsis.

There being no further business before it, the Board adjourned to meet at 10 a. m., the 9th.

NATIONAL ARMORY, MASS.,
April 9, 1878.

Board met pursuant to adjournment.

Present: All the members and the recorder.

It having been stated to the Board that the Ward-Burton magazine-gun worked satisfactorily with brass shells, the test was resumed with

United States Cartridge Company's cartridges. Trial having demonstrated that the same trouble existed as before, the gun was withdrawn by the commanding officer, National Armory.

The Sharps Rifle Company presented a magazine-gun which the Board examined and then submitted to the prescribed tests. The results are stated in the synopsis.

There being no further business before it, the Board adjourned to meet at 10 a. m., the 10th.

NATIONAL ARMORY, MASS.,
April 10, 1878.

The Board met pursuant to adjournment.

Present: Major Parker, Major Farley, and the recorder.

Absent: Colonel Benton, on official duty.

The following letter was received, read, and entered on the record:

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, April 8, 1878.

SIR: In an indorsement of April 4, 1878, approved by the Secretary of War, which was communicated for the information of your Board, I used the following language: "A gun of cal. 0".44 need not be thrown out, if the trial will prove its merits when using regulation ammunition." My meaning is this: that a gun, say of cal. 0".44, using a cartridge smaller than the regulation, say with 40 or 50 grains powder, need not be thrown out, if in the opinion of the Board its trial will prove that it will do equally well, if made of cal. 0".45, and use the regulation cartridge. The idea being, that as a magazine-gun for the military service *must* use the regulation cartridge and be of cal. 0".45, there is no use trying a gun of smaller caliber and using a lighter cartridge, if the Board believe that it would fail as a cal. 0".45 using the regulation cartridge, which will necessarily strain the system so much more.

Respectfully, your obedient servant,

S. V. BENÉT,
Brigadier General, Chief of Ordnance.

Lieut. Col. J. G. BENTON,
President of the Board on Magazine-Guns,
National Armory, Springfield, Mass.

The Board then resumed consideration of the Sharps Rifle Company's magazine-gun.

After deliberation it was decided to slightly modify the extractor and then resume the test.

One guard-screw was found broken. A new one was substituted.

Mr. C. B. Hunt presented a magazine-gun, cal. 0".44. The Board examined this arm but decided to take no action in regard to it until the full Board was present.

The alteration of the extractor having been completed, the firing was resumed with Sharps Rifle Company's gun. The results are given in the synopsis.

There being no further business before it, the Board adjourned to meet at 10 a. m., the 12th.

NATIONAL ARMORY, MASS.,
April 12, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Mr. C. B. Hunt presented his 0".44-caliber magazine-gun, and drawings of a similar gun of 0".45 caliber intended to use the service-cartridge.

He explained the gun and drawings to the Board. In presence of the Board he fired 15 cartridges from his gun, loading from the magazine, by way of showing its working qualities.

After discussion, the following decision was directed to be entered on the record:

"The Board is of opinion that Mr. Hunt's system of a magazine-gun possesses merit, but as the piece submitted by him is not of the regulation caliber, the Board is unable to subject it to the prescribed tests. It therefore suggests that a gun of 0''.45 caliber be submitted for trial."

A copy of this decision was directed to be furnished Mr. Hunt.

There being no further business before it, the Board adjourned to meet at 10 a. m., the 13th.

NATIONAL ARMORY, MASS.,
April 13, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

No guns having been presented and there being no business before it, the Board adjourned to meet at 10 a. m., the 15th.

NATIONAL ARMORY, MASS.,
April 15, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Mr. Borchardt presented a Sharps Rifle Company's magazine-gun.

Mr. H. H. Lewis presented a magazine-gun called the Lewis-Rice gun.

These guns were examined by the Board and then submitted to the prescribed tests. The results are stated in the synopsis.

Maj. A. R. Buffington, U. S. A., submitted a magazine-gun of his invention which he explained to the Board.

The Board then adjourned to meet at 10 a. m., the 16th.

NATIONAL ARMORY, MASS.,
April 16, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Major Buffington informed the Board that he desired to slightly modify his gun before it was submitted to the tests; to this the Board assented.

The Board then decided to observe the effect produced on cartridges jolted up and down in a magazine-tube. For this purpose a gun was selected whose caliber was sufficiently large to serve as a magazine-tube. The cartridges were put in the barrel, with a spring of the kind ordinarily used in magazine-guns below them. The gun was secured in a frame having a vertical motion in guides. To the upper end of the frame one end of a belt, which passed over a pulley above, was attached. The other end of the belt was fastened to a crank on a lathe. The length of the belt was such that the frame, gun, &c., had a fall of 5½ inches.

The cartridges were thus jolted up and down for 5 minutes when they were taken out and examined.

The bullets of the lower cartridges were somewhat squared up, and the bases of the cartridges just over the fulminate showed marks of the lead bearing on them. The operation was repeated for 15 minutes, with the result before stated, only in a more marked degree. The cartridges were then returned to the tube for 1 hour and 10 minutes. At the end of this time they were again examined, when those at the bottom of the tube were found to have their bullets upset so as to nearly form cylinders. No explosion occurred during the trial.

There being no other business before it, the Board adjourned until 10 a. m., the 17th.

NATIONAL ARMORY, MASS.,
April 17, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board directed a continuation of the tests of cartridges jolted in the magazine, using the various kinds now in service, viz: Frankford, United States Cartridge Company's, Union Metallic Cartridge Company's, and the Winchester Arms Company's.

There being no further business before it, the Board adjourned to meet at 10 a. m., the 18th.

NATIONAL ARMORY, MASS.,
April 18, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

There being no business before it, the Board adjourned to meet at 10 a. m., the 19th.

NATIONAL ARMORY, MASS.,
April 19, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

There being no business before it, the Board adjourned to meet at 10 a. m., the 20th.

NATIONAL ARMORY, MASS.,
April 20, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

There being no business before it, the Board adjourned to meet at 10 a. m., the 22d.

NATIONAL ARMORY, MASS.,
April 22, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Major Buffington having made such changes in his gun as he desired on its first presentation, now submitted it for the action of the Board.

Mr. Borchardt submitted the Sharps Rifle Company's gun in its improved form. The Board proceeded to test these guns, with the results stated in the synopsis.

The Board then adjourned to meet at 10 a. m., the 23d.

NATIONAL ARMORY, MASS.,
April 23, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Major Buffington presented his gun, slightly modified, and Mr. J. J. Sweeny, on behalf of the Winchester Arms Company, submitted a magazine-gun known as the Hotchkiss gun. The Board proceeded to test these guns, with results as stated in the synopsis.

The Board then adjourned to meet at 10 a. m., the 24th.

NATIONAL ARMORY, MASS.,
April 24, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board continued the tests of the Hotchkiss and Buffington guns, after which it adjourned to meet at 10 a. m., the 25th.

NATIONAL ARMY, MASS.,
April 25, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board continued the test of the Sharps Rifle Company's gun, No. 8.

Mr. E. Whitney presented four magazine-guns, called respectively the Tiesing-Baldwin, Tiesing-Berdan, Tiesing, and the Burgess. The first two were caliber 0''.42 and the others caliber 0''.45.

Mr. Whitney stated that he was not ready to submit any of these guns formally to the Board, but would like to have a preliminary examination made of them, after which he would fire them in the presence of the Board. This having been done, Mr. Whitney withdrew the guns.

The Board then adjourned, to meet at 10 a. m. the 26th.

NATIONAL ARMORY, MASS.,
April 26, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

A new extractor having been provided, the Board continued the test of the Hotchkiss gun.

The Winchester Repeating Arms Company presented one of their repeating rifles, which was fired a number of times in the presence of the Board. As this gun was not adapted to the service cartridge, the

Board was unable to continue the test. It, however, adopted the following resolution:

"In view of the well-established reputation of this arm, the Board would suggest that a gun be submitted capable of firing the United States service ammunition."

The Board directed that a copy of this resolution be furnished the Company.

The Board then proceeded with the tests of the Buffington magazine-gun, after which it adjourned to meet at 10 a. m. the 27th.

NATIONAL ARMORY, MASS.,
April 27, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

There being no business before it, the Board adjourned to met at 10 a. m. the 29th.

NATIONAL ARMORY, MASS.,
April 29, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board directed the following telegram to be sent the Evans Rifle Manufacturing Company:

NATIONAL ARMORY,
Springfield, Mass., April 29, 1878.

EVANS RIFLE MANUFACTURING COMPANY,
Mechanics Falls, Me.:

Board expects to adjourn until next June. Do you wish your gun tried now or then? Answer.

BENTON,
President of Board.

The Board then continued the test of the Hotchkiss gun, No. 9, after which it adjourned to meet at 10 a. m. the 30th.

NATIONAL ARMORY, MASS.,
April 30, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Letter was received from Evans Rifle Manufacturing Company, stating that they would wait until June before submitting their guns.

There being no business before it, the Board adjourned to meet at 10 a. m. May 1, 1878.

NATIONAL ARMORY, MASS.,
May 1, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Letter was received from Evans Rifle Manufacturing Company, stating that their guns were arranged for use of Lowell cartridges and inquiring if such were on hand at the armory.

The following letter was sent in reply:

NATIONAL ARMORY, MASS.,
May 1, 1878.

GENTLEMEN: Your letter of yesterday is received. In reply to it, I have to state that the Board on Magazine Guns has decided to test all arms submitted to it with the service-cartridge made at the Frankford Arsenal. All the arms thus far have been tested with this cartridge.

Respectfully, your obedient servant,

J. G. BENTON,
Lieutenant Colonel, and President of Board.

EVANS RIFLE MANUFACTURING COMPANY,
Mechanics Falls, Me.

There being no business before it, the Board adjourned to meet at 10 a. m. the 2d.

NATIONAL ARMORY, MASS.,
May 2, 1878.

The Board met pursuant to adjournment.
Present: All the members and the recorder.
There being no business before it, the Board adjourned to meet at 10 a. m. the 3d.

NATIONAL ARMORY, MASS.,
May 3, 1878.

The Board met pursuant to adjournment.
Present: All the members and the recorder.
There being no business before it, the Board adjourned to meet at 10 a. m. the 4th.

NATIONAL ARMORY, MASS.,
May 4, 1878.

The Board met pursuant to adjournment.
Present: Colonel Benton, Major Farley, and the recorder.
Absent: Major Parker, by permission of the Board.
There being no business before it, the Board adjourned to meet at 10 a. m. the 6th.

NATIONAL ARMORY, MASS.,
May 6, 1878.

The Board met pursuant to adjournment.
Present: Colonel Benton, Major Farley, and the recorder.
Absent: Major Parker, by permission of the Board.
There being no business before it, the Board adjourned to meet at 10 a. m. June 18, 1878, in accordance with the authority contained in the following order:

[Special Orders No. 97.]

HEADQUARTERS OF THE ARMY, ADJUTANT-GENERAL'S OFFICE,
Washington, May 6, 1878.

[Extract.]

* * * * * * *

2. By direction of the Secretary of War, the Board appointed to meet at the National Armory, Springfield, Mass., by General Orders No. 115, December 18, 1877, from this

office, to consider and recommend a magazine-gun, should one be found suitable for the military service, is authorized to adjourn until June 18, proximo, and the members not on duty at the Armory will rejoin their proper stations. The Board will reassemble at Springfield on June 18, 1878.

* * * * * * *

By command of General Sherman.

E. D. TOWNSEND,
Adjutant-General.

Official:
L. H. PELOUZE,
Assistant Adjutant-General.

NATIONAL ARMORY, MASS.,
June 18, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

A magazine-gun forwarded by express by Mr. B. Burton was received and entered on the docket as No. 11.

Mr. J. J. Sweeny presented, on behalf of the Winchester Repeating Arms Company, one of their repeating rifles and the Hotchkiss magazine-gun, which were entered on the docket as Nos. 13 and 12, respectively.

Mr. R. S. Chaffee presented a magazine-gun, caliber 0″.44. He explained the system of his gun to the Board, and in its presence fired about 50 rounds to show its working qualities.

After discussion, the Board notified Mr. Chaffee that it could not test this gun unless adapted to the service-cartridge.

The Board then proceeded to test the Winchester and Hotchkiss guns, as stated in the synopsis.

The Board then adjourned to meet at 10 a. m., the 19th.

NATIONAL ARMORY, MASS.,
June 19, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Mr. Josiah Dupau presented a Springfield rifle altered so as to be used in conjunction with a special form of cartridge-box designed to secure greater rapidity of fire. After showing the capabilities of this system to the Board, and as the results of the trial did not meet his expectation, Mr. Dupau withdrew his gun.

Mr. H. A. Lewis presented a magazine-gun called the Lewis-Rice gun, which was entered on the docket as No. 14.

Letter from Mr. J. C. Hodges stating that he had a magazine-gun, caliber 0″.32, and asking if the Board would consider it, was submitted to the Board by Colonel Benton. After discussion, the Board directed the recorder to inform Mr. Hodges that it could not test his gun until adapted to the service-cartridge.

The Board then proceeded with the tests of the Winchester, Hotchkiss, and Lewis-Rice guns, as stated in the synopsis, after which it adjourned to meet at 10 a. m., the 20th.

NATIONAL ARMORY, MASS.,
June 20, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board proceeded with the trial of the Lewis-Rice and Burton guns.

The latter gun not working satisfactorily, a letter was directed to be sent Mr. Burton explanatory of the difficulty.

The Board then adjourned to meet at 10 a. m., the 21st.

NATIONAL ARMORY, MASS.,
June 21, 1878.

The Board met pusuant to adjournment.

Present: All the members and the recorder.

Telegram was received from Mr. H. A. Lewis, withdrawing the Lewis-Rice gun.

The Board considered the letter of Mr. C. B. Hunt, referred to it by the Chief of Ordnance for report. Mr. Hunt desired to have a magazine-gun on his system made at the National Armory, at the expense of the United States, for trial before the Board on Magazine Arms. After discussion, it was resolved that "since the Board examined the plan of Mr. Hunt, other plans have been submitted which are thought to possess greater merit. It cannot, therefore, recommend Mr. Hunt's gun to be made at government expense, as it would only feel warranted to make that recommendation when the plan presents great promise of superiority over all others submitted to the Board."

Letters were sent Mr. E. Whitney, Mr. G. F. Clemmons, Mr. W. H. Miller, Messrs. Smith & Wesson, E. Remington & Sons, and to the Sharps Rifle Company, stating that the Board was in session and ready to try any magazine-guns they might wish to submit.

There being no further business before it, the Board adjourned to meet at 10 a. m., the 22d.

NATIONAL ARMORY, MASS.,
June 22, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

A letter was addressed to General Ames, notifying him that the Board was in session and prepared to test his gun when presented. The Board considered the letter of Mr. Joe V. Meigs, referred to it by the Chief of Ordnance. Mr. Meigs desired to have a Springfield rifle altered on his plan to a magazine-gun, at the National Armory, Mass., at the expense of the United States, for trial before the Board on Magazine-arms. After discussion, it was resolved that "the Board is of the opinion that it would only be admissible for it to recommend the manufacture of an arm at the Armory, at government expense, which is to compete with those presented by others, when the plan presented great merits and a promise of superiority over all other guns. Several systems of magazine-arms have been submitted to the Board for trial and appear to be much more simple and less expensive than this proposed alteration of the Springfield gun. The wooden model and rude sketches inclosed are only sufficient to give the Board information of the crude ideas enter-

tained by the inventor, and it is not able from these to say that it possesses these great merits. Of the two advantages suggested by the Chief of Ordnance in his indorsement, the Board are not able to agree with him in the first, for upon examination as to the cost and labor necessary for the construction of this arm it is found that there are such fundamental changes that the alteration of plant would be quite as great as that required for a new gun of entirely different system. In connection with this attention is respectfully invited to the inclosed report from the master machinist and draughtsman of the armory. It may be proper in this connection to state that the Board has been advised that several plans for adapting a magazine to the Springfield system are being prepared by inventors at their own expense to be submitted to the Board."

The Board then proceeded with the tests of the Winchester and Hotchkiss guns, after which it adjourned to meet at 10 a. m., the 24th.

NATIONAL ARMORY, MASS.,
June 24, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board examined the drawings of a magazine-gun submitted by Mr. B. Burton. After discussion, the Board declined, in accordance with its previous rulings, to recommend the manufacture of this gun, as requested by Mr. Burton, at the expense of the United States. The recorder was directed to notify Mr. Burton of this decision.

There being no further business before it, the Board adjourned to meet at 10 a. m., the 25th.

NATIONAL ARMORY, MASS.,
June 25, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Letter was received from Mr. B. Burton—in reply to letter of Board of June 21, informing him that his gun had failed to operate satisfactorily, and inquiring if he desired to correct the difficulty—in which he requested the Board to make certain changes, practically a development of his system. The Board, after consideration, decided that this was beyond its province, and directed the recorder to notify Mr. Burton that his application could not be entertained.

Mr. W. H. Miller presented a Springfield rifle altered to a magazine-gun. After examining the system the Board proceeded to test it. The gun failing, however, to meet Mr. Miller's expectations, he asked for and obtained permission to withdraw it.

There being no further business before it, the Board adjourned to meet at 10 a. m. the 26th.

NATIONAL ARMORY, MASS.,
June 26, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Telegram was sent the Evans Rifle Manufacturing Company inquiring when they would submit their gun.

There being no further business before it, the Board adjourned to meet at 10 a. m. the 27th.

NATIONAL ARMORY, MASS.,
June 27, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Letter was received from Mr. J. C. Hodges stating advantages claimed for his gun (cal. 0''.32), and asking for reconsideration of his application to have it tested. After discussion the recorder was directed to notify Mr. Hodges that he could submit his gun for examination if he desired, but that it could not be tested unless adapted to the service-cartridge.

Letter was sent the Evans Rifle Manufacturing Company stating, in reply to their telegram of June 26, that the Board would test their gun July 15, time designated by them.

There being no business before it, and no reason to anticipate any for several days, the Board adjourned to meet at the call of the President.

NATIONAL ARMORY, MASS.,
July 9, 1878.

The Board met at the call of the President.

Present: All the members and the recorder.

Mr. J. Keene presented, on behalf of E. Remington & Sons, a magazine-gun, which he explained to the Board.

Mr. H. A. Lewis submitted the Lewis-Rice gun, somewhat modified since previous trials.

The Board proceeded to test these guns, after which it adjourned to meet at 10 a. m. the 10th.

NATIONAL ARMORY, MASS.,
July 10, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board continued the test of the Remington magazine-gun, after which it adjourned to meet at 10 a. m. the 11th.

NATIONAL ARMORY, MASS.,
July 11, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board directed that a letter be addressed the Chief of Ordnance, United States Army, stating that in its opinion it was advisable to limit the time of receiving guns to the 31st of August; also, that Mr. B. Burton be notified that his gun, shipped the 2d, had not yet been received.

There being no other business before it, the Board adjourned to meet at 10 a. m. the 12th.

NATIONAL ARMORY, MASS.,
July 12, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board examined photographs and description of cal. 0''.32 gun, contained in Mr. J. C. Hodges's letter of July 2.

The Board directed the recorder to notify Mr. Hodges that it had heretofore declined to test any gun presented unless adapted to the service-cartridge, and that it could make no discrimination in his favor.

There being no other business before it, the Board adjourned to meet at 10 a. m. the 13th.

NATIONAL ARMORY, MASS.,
July 13, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board continued the tests of the Remington magazine-gun; on the completion of which, there being no other business before it, it adjourned to meet at the call of the President.

NATIONAL ARMORY, MASS.,
July 20, 1878.

The following circular was this day sent the firms and individuals named below, in accordance with letter received from War Department, Adjutant-General's Office, dated Washington, July 18, 1878: B. Burton, E. Remington & Sons, C. B. Hunt, Alfred J. Wolf, E. F. Edgecomb, F. Vetterly, J. H. Reece, G. F. Clemmons, Smith & Wesson, Winchester Arms Company, J. C. Hodges, General A. Ames, James Trabue, Jos. V. Meigs, W. F. Snedden, Sharps Rifle Company, Colts Patent Fire Arms Manufacturing Company, Evans Rifle Company, H. A. Lewis, Whitney Arms Company, William H. Miller:

[Circular.]

OFFICE OF THE BOARD ON MAGAZINE ARMS, NATIONAL ARMORY,
Springfield, Mass., July 19, 1878.

SIR: I have the honor to inform you that, by direction of the Secretary of War, the Board on Magazine Guns will receive no arms for examination and trial after 12 m. the 31st of August next.

Very respectfully, your obedient servant,

JOHN E. GREER,
Captain of Ordnance, U. S. A., Recorder of Board.

NATIONAL ARMORY, MASS.,
July 30, 1878.

The Board met pursuant to the call of the President.

Present: All the members and the recorder.

Board discussed the general features of and qualities requisite for a magazine-gun, after which it adjourned to meet at 10 a. m. the 31st.

NATIONAL ARMORY, MASS.,
July 31, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Board continued the discussion of previous day, after which it adjourned to meet at 10 a. m. the 1st proximo.

NATIONAL ARMORY, MASS.,
August 1, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Mr. J. J. Sweeny, agent for the Winchester Repeating Arms Company, submitted a Hotchkiss magazine-gun (No. 18), which the Board proceeded to test, after which it adjourned to meet at 10 a. m. the 5th.

NATIONAL ARMORY, MASS.,
August 5, 1878.

The Board met pursuant to adjournment.

Present: Colonel Benton, Major Parker, and the recorder.

Absent: Major Farley, by permission of the Board.

Mr. J. J. Sweeny, agent for the Winchester Repeating Arms Company, submitted a Hotchkiss magazine-gun (No. 19), which the Board proceeded to test, after which it adjourned to meet at 10 a. m. the 6th.

NATIONAL ARMORY, MASS.,
August 6, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Board continued the test of the Hotchkiss magazine-gun No. 19, after which it adjourned to meet at 10 a. m., the 7th.

NATIONAL ARMORY, MASS.,
August 7, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Board discussed the merits of some of the guns before it, after which it adjourned to meet at 10 a. m., the 8th.

NATIONAL ARMORY, MASS.,
August 8, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Board continued the test of the Hotchkiss magazine-gun No. 19, on completion of which it proceeded to test the Lewis-Rice magazine-gun (No. 20), which had been submitted by letter of the 7th.

Letter was addressed the Whitney Arms Company in reply to their letter of the 6th, stating that the Board would test their gun any time the coming week.

The Board then adjourned to meet at the call of the President.

NATIONAL ARMORY, MASS.,
August 15, 1878.

The Board met at the call of the President.

Present: All the members and the recorder.

The Whitney Arms Company submitted two magazine-guns, the Burgess and the Tiesing, which the Board proceeded to test, on the completion of which, there being no other business before it, it adjourned to meet at 10 a. m., the 31st.

NATIONAL ARMORY, MASS.,
August 31, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Magazine-guns were submitted by the Whitney Arms Company (the Burgess), Mr. G. F. Clemmons (alteration of Springfield rifle), Mr. James Lee, and Mr. R. S. Chaffee. A model of magazine intended to be applied to the Hotchkiss gun was submitted by Lieut. A. H. Russell, U. S. A.

The Board permitted Mr. Lee and Mr. Chaffee to retain their guns for a few days in order to make certain additions to them.

The Board then proceeded to test the Burgess gun, after which it adjourned to meet at 10 a. m., the 2d.

NATIONAL ARMORY, MASS.,
September 2, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board, after discussion,

"*Resolved*, That in the supplementary tests the rusting prescribed in the second test be omitted, as sufficient information on that point was obtained by the regular rust-tests through which the guns have satisfactorily passed, but that the excessive charges required by that test be fired.

"That to determine the comparative rapidity of fire and facility of manipulation, as contemplated by the third supplementary test, each gun be fired 20 shots by three enlisted men of the armory detachment, loading from the cartridge-box and firing with aim at a target 6′ by 24′ 100 yards distant. The average of the three trials to be the recorded time of firing 20 rounds. The magazine to be loaded from the cartridge-box before the start, the remainder of the cartridges to be fired away first, using the gun as a single-shooter, and the magazine to be emptied last.

"That under the fourth supplementary test, in addition to the test already made of giving a jolting motion to a column of cartridges in a vertical tube with the spiral magazine-spring, a column of six cartridges be jolted in a tube without the spring, and, if there be no explosion, then that the lowest bullet in the column be replaced by a pointed steel plug, first using the spring below the plug, and, in event of its not producing explosion, that it be tried without the spring. Also, if there is no explosion resulting from the jolting tests, that the tube containing the column of cartridges heavily weighted at the lower end to insure its vertical position, and having the spring at the bottom of the tube, be dropped from a height of 20 feet upon a pavement, and, if there

is no explosion, that it be dropped as before without the spring in the tube. Afterward, that a pointed steel plug replace the lowest bullet in the column, and it be dropped with the spring in the tube; then, if there is no explosion, that the dropping be finally tried with the spring removed. These tests to be applied equally to the Frankford and exterior-primed cartridges.

"That the comparative convenience of carrying the different guns and executing the manual of arms be considered and tested."

The Board then proceeded to test the Clemmons alteration of the Springfield rifle and the Burgess gun—the latter having been repaired—after which it adjourned to meet at 10 a. m. the 3rd.

NATIONAL ARMORY, MASS.,
September 3, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board, after discussion, resolved to submit to the supplementary tests the Sharps Rifle Company's gun No. 8, the Winchester, No. 13, the Remington, No. 17, and the Hotchkiss, No. 19. The exhibitors were notified as to what day the trials would be made.

The jolting of cartridges in accordance with tests adopted the 2d was commenced.

The Board then adjourned to meet at 10 a. m., the 4th.

NATIONAL ARMORY, MASS.,
September 4, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board proceeded with the firing of the Sharps, Winchester, Remington, and Hotchkiss guns, three enlisted men of the armory detachment having been selected in accordance with resolution of the 2d. A breech-bolt having the handle vertical when the bolt is locked was applied by Captain Greer to the Hotchkiss gun, as typical of bolt-guns, and submitted by him with the view of facilitating the execution of the manual of arms, particularly in the "carry," "present," "support," and "arms port." The Board then proceeded to test the comparative convenience of carrying the different arms and the execution of the manual.

Captain Greer's bolt was also tried.

The Board then adjourned to meet at 10 a. m., the 5th.

NATIONAL ARMORY, MASS.,
September 5, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board, after discussion,

Resolved, That in place of that part of the resolution passed by the Board on the 2d of September relating to the rust-test, the following be substituted:

"That all arms selected for supplementary tests be rusted simultaneously, *i. e.*, that they be immersed at the same time, for ten minutes, in the same sal-ammoniac solution, and afterward exposed side by side to its corroding action for four days, when they will each be fired five rounds with service-cartridges; then, without cleaning, fired five rounds with 120 grains of powder and a ball weighing 1,200 grains; after this, each gun to stand twenty-four hours without cleaning, and then to be thoroughly examined."

The Board then resumed the tests of the Burgess, Winchester, and Hotchkiss guns, after which it adjourned to meet at 10 a. m., the 6th.

NATIONAL ARMORY, MASS.,
September 6, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

There being no business before it, the Board adjourned to meet at 10 a. m., the 10th, unless sooner convened by the President.

NATIONAL ARMORY, MASS.,
September 10, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Letter was addressed the Whitney Arms Company, in regard to the Burgess gun, in reply to their letter of the 7th.

There being no other business before it, the Board adjourned to meet at 10 a. m., the 11th.

NATIONAL ARMORY, MASS.,
September 11, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Mr. G. F. Clemmons submitted his magazine-gun (alteration of the Springfield rifle), which the Board proceeded to test, after which it adjourned to meet at 10 a. m., the 12th.

NATIONAL ARMORY, MASS.,
September 12, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

Board engaged in general discussion as to merits of guns before it, after which it adjourned to meet at 10 a. m., the 13th.

NATIONAL ARMORY, MASS.,
September 13, 1878.

The Board met pursuant to adjournment.
Present: All the members and the recorder.
The Board proceeded to ascertain the effect produced on the gun by the accidental insertion of cartridges reversed in direction in the magazine. It was found that with the Winchester and Remington guns the cartridges could be removed, though with considerable difficulty, without dismounting any of the parts.
With the Sharps gun it was necessary to remove the cap to the magazine, the spring, and the cartridge follower. All of these guns were for the time disabled.
With the Hotchkiss no trouble whatever was experienced, the cartridges feeding out in the usual manner. Those cartridges which were reversed in direction had merely to be pushed aside. It should be stated that it is impossible to insert the cartridges reversed in the Hotchkiss by the hands alone.
The Board then adjourned to meet at 10 a. m., the 14th.

NATIONAL ARMORY, MASS.,
September 14, 1878.

The Board met pursuant to adjournment.
Present: All the members and the recorder.
The Board proceeded to test the Chaffee and Burgess guns, the latter having been repaired, after which it adjourned to meet at 10 a. m., the 16th.

NATIONAL ARMORY, MASS.,
September 16, 1878.

The Board met pursuant to adjournment.
Present: All the members and the recorder.
The Board directed the recorder to notify the Whitney Arms Company, E. Remington & Sons, and the Sharps Rifle Company that their guns would be submitted to the supplementary tests the 17th.
The Board then adjourned to meet at 10 a. m., the 17th.

NATIONAL ARMORY, MASS.,
September 17, 1878.

The Board met pursuant to adjournment.
Present: All the members and the recorder.
The Board proceeded to apply the supplementary tests to the Sharps, Remington, Burgess, Hotchkiss, and Winchester guns, after which it adjourned to meet at 10 a. m., the 19th.

NATIONAL ARMORY, MASS.,
September 19, 1878.

The Board met pursuant to adjournment.
Present: All the members and the recorder.
The Board discussed the merits of the arms before it, after which it adjourned to meet at 10 a. m., the 20th.

NATIONAL ARMORY, MASS.,
September 20, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board continued the discussion of the previous day.

There being no other business before it, the Board adjourned to meet at 10 a. m., the 21st.

NATIONAL ARMORY, MASS.,
September 21, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board completed the supplementary tests with the Hotchkiss, Winchester, Sharps, Burgess, and Remington guns, after which it adjourned to meet at 10 a. m., the 23d.

NATIONAL ARMORY, MASS.,
September 23, 1878.

The Board met pursuant to adjournment.

Present: All the members and the recorder.

The Board decided to submit the Hotchkiss gun No. 19 to a final test for rapidity, using it as a magazine-gun, in comparison with itself as a single-loader and with the service Springfield rifle; 6 cartridges to be fired; the magazine and chamber to be loaded in the first case, and in the latter two, 1 cartridge to be inserted in the chamber, the others to be taken from the cartridge-box; the recorded time to be the mean of three trials.

After discussion, the final report of the Board was adopted.

Major Parker then offered the following resolution:

Resolved, That as the upright position of the bolt-handle assimilates that class of guns to the hammer-gun, to which our Army is accustomed, improves their appearance, and obviates any necessity for a change in the manual of arms, the Board recommend that a few locking-tubes having this position of the handle, be issued with these arms, to enable those using them in service to determine whether or not it is in other respects and upon the whole as desirable as the horizontal handle.

To this resolution Major Farley voted no; Major Parker voted yes; Colonel Benton voted no.

Major Farley submitted the following explanation in regard to his vote:

"He can find nothing in the record to show why he should assent to a change which, in his opinion, militates against the efficiency of the magazine-arm selected by the Board. A plan has been suggested to simply turn up the bolt to a vertical position, and lock the same for convenience in carrying the gun at the support arms, which does not carry with it a loss of time or complex motion incident to the bolt being manipulated on the *left* side of the piece. Future experience and experiment will determine the compromise necessary for a new arm and an old manual."

The Board then proceeded to make the final test with the Hotchkiss gun, No. 19, after which it adjourned *sine die*.

Classification of magazine-arms, founded on the method by which cartridges are fed from the magazine.

- Magazine-arms supply chamber with cartridges from—
  - 1st, butt-stock
    - 1st, by a spring
      - 1st, direct ..... Hotchkiss. Lewis-Rice. Spencer.
      - 2d, indirect
        - 1st, by rotating barrel about axis parallel to it into line with magazine. ..... Scott and Triplet.
        - 2d, to position opposite receiver ..... Clemmons.
    - 2d, by a ratchet, which is—
      - 1st, automatic ..... Chaffee.
      - 2d, operated by hand. ..... Springfield-Miller.
    - 3d by a spiral cam (screw-motion). ..... Evans.
  - 2d, tip-stock
    - by a spring—
      - on a carrier which is—
        - 1st, sliding, at right angles to axis of bore ..... Winchester. Henry. Hunt. Vetterly.
        - 2d, rotating—
          - 1st, to position oblique to axis of bore ..... Burton. Ward-Burton. Sharps. Remington.
          - 2d, to position parallel with axis ..... Tiesing. Burgess.
        - 3d, sliding and rotating— ..... Buffington.
  - 3d, magazine on top of barrel
    - by a spring—
      - to position parallel to axis of bore and above receiver—
        - and by gravity
          - into line with axis of bore. ..... Franklin.
  - 4th, magazine below bolt
    - by a spring (vertically)—
      - to position opposite center of chamber. ..... Lee.
  - 5th, revolving chambers. ..... Hodges. Colt's repeating-rifle. Revolving pistols.

Classification of all magazine-guns before the Board, founded on the motions of the principal part by which the breech is opened and closed.*

- Breech-loading small-arms have—
  - fixed chambers closed by—
    - movable breech-blocks which are—
      - 1st, sliding.
        - in line of axis of barrel by—
          - 1st, direct action, *i. e.*, bolt-guns having—
            - 1st, concealed locks .... Hotchkiss. Remington. Burton. Ward-Burton. Franklin. Lee. Sharps Rifle Company.
            - 2d, center locks .... Hunt.
          - 2d, indirect action, *i. e.*, moved by levers from—
            - below .... Winchester. Burgess. Tiesing.
      - 2d, sliding and rotating .... Buffington. Chaffee.
      - 3d, rotating about an axis—
        - at 90° to axis of barrel, and—
          - horizontal, lying—
            - 1st, above axis of barrel, and in—
              - front .... Springfield-Miller. Springfield-Clemmons.
            - 2d, below axis of barrel, and in—
              - front, moved from—
                - below (by a lever) .... Lewis-Rice.

*Classification similar to that given in Ordnance Memorandum No. 15.

Description of guns and results of tests applied by the board.

BREECH-LOADING SMALL-ARMS HAVING A FIXED CHAMBER CLOSED BY A MOVABLE BREECH-BLOCK WHICH SLIDES IN THE LINE OF THE BARREL BY DIRECT ACTION, *i. e.*, BOLT-GUNS WHICH HAVE—

1.—CONCEALED LOCKS.

HOTCHKISS.
REMINGTON.
SHARPS.
FRANKLIN.
BURTON.
WARD-BURTON.
LEE.

Hotchkiss Magazine-Gun, No. 9.

This gun belongs to that system in which a fixed chamber is closed by a bolt, by direct action, and in which the lock is concealed.

The receiver shown in Figs. 1, 2, and 3, Plate I, is cut through at the rear for the reception of the bolt; it is also cut away at the side to receive the handle when the bolt is locked. The breech-bolt is composed of three parts, viz: the body or locking-tube, Fig. 4, of which the handle forms a part; the bolt-head, Fig. 5; and the rear portion, or cocking-piece, Fig. 6, to which the firing-pin is secured by a screw-thread. The body of the bolt is hollowed out for the firing-pin and spring; the latter bears on a shoulder near the rear end of the body. The bolt-head, which supports the cartridge at the instant of fire, carries the extractor, Fig. 7, which is attached to its side by means of a dove-tail tenon. On the bolt-head is a projection, B, which, turning in a groove, C, in the body of the bolt, serves to hold the two parts together. The cocking-piece is held in contact with the body of the bolt by the tension of the firing-pin spring. The firing-pin, Fig. 8, is flattened near its front end. The bolt-head is prevented from turning about the pin, when the bolt is withdrawn, by the tenon on the extractor which extends into the firing-pin hole nearly to the flattened surface of the pin. A projection, D, on the bolt-head enters a corresponding recess in the receiver when the bolt is locked; consequently, the bolt-head cannot turn when the body of the bolt is rotated about its axis, as in the act of locking the piece. The cocking-piece is shown in Fig. 6. A projection, E, fits in a recess, F, on the rear of the body of the bolt. The form of this projection, and of its corresponding recess, is such that when the bolt is unlocked the cocking-piece is cammed back beyond the nose of the sear, or upper extremity of the trigger, withdrawing the point of the firing-pin within the face of the bolt-head. When the bolt is locked, which is done by turning down its handle in the cut in the receiver, the firing-pin spring is compressed. By pressing on the trigger, the sear is drawn from the cocking-piece, and the firing-pin, driven forward by its spring, explodes the cartridge.

The form of the side cut in the receiver at its rear, G, Fig. 2, is such that the breech-bolt is cammed forward as it is turned to the locking position, forcing the cartridge into the chamber. As the firing-pin cannot reach the cartridge until the bolt is locked, accidental explosions are avoided.

The shape of the cut at front, H, Fig. 2, is such as to cam back the

bolt during the unlocking, starting the empty shell. The shells are thrown out that side of the receiver which is cut away. The extractor being on the same side, the shells are unsupported against its side pull the instant they leave the chamber. Their front ends being consequently deflected from the axis of the receiver, the shells fall to the ground.

The magazine is in the butt-stock. A hole is drilled in the receiver at its rear end, below the breech-bolt, oblique to the axis of the bore, Fig. 1. Through this hole the cartridges are fed from the magazine into the receiver, when the bolt forces them into the chamber. The trigger, shown in Figs. 9 and 10, bends around the magazine-tube. Two cartridge-stops, I and J, Fig. 1, are connected with it, one above and one below the cartridges. When the magazine is filled, which is done by pressing the cartridges into it from the receiver, the front cartridge bears against the lower stop, as seen in Fig. 1. By pressing on the trigger the lower stop is depressed below the level of the magazine, and the first cartridge, under the pressure of the magazine-spring, slips by and bears against the under side of the bolt. As the lower stop is depressed, the upper one descends, checking a second cartridge from passing through. When the bolt is withdrawn, the first cartridge is driven up by the spring into the receiver, while the second one, which has now passed the upper stop, is in turn checked by the lower one. It will be seen, therefore, that the pressing of the trigger to fire one cartridge, permits the next one to partly enter the receiver, the operation being completed when the bolt is withdrawn with the empty shell. The slide K locks the trigger when the piece is carried at full-cock; it also locks the breech-bolt by forcing the nose of the sear in a groove in the bottom of the bolt.

A magazine cut-off enables the piece to be used as a single-loader.

As a magazine-gun, 3 motions are necessary to operate, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

Five cartridges are carried in the magazine and 1 in the chamber.

SYNOPSIS OF TESTS.

APRIL 23, 1878.

The safety-test was complied with by Mr. J. J. Sweeny, representing the gun. Time, 27 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun, 22 shots were fired; 16 struck the target, 5 cartridges remained in the magazine. 3 cartridges were thrown out unfired, caused by two cartridges escaping from the magazine at once, one of which entered the chamber, while the other fell to the ground through the space cut away on the right side of the receiver; this occurred three times.

As a single-loader, 39 shots were fired; 25 struck the target. This lack of accuracy was caused by the fatigue of the marksman, who was continuously testing this and other guns.

II.—*Rapidity at will.*

As a magazine-gun, 17 shots were fired; 2 cartridges remained in the magazine.

As a single-loader, 27 shots were fired.

III.—*Endurance.*

The gun worked well throughout the test, though a little more force was required to operate the breech-bolt during the last 100 rounds.

APRIL 24, 1878.

IV.—*Defective cartridges.*

First fire.—Decided escape of gas. On withdrawing the breech-bolt the extractor was found broken. The test was then discontinued until a new extractor could be provided.

APRIL 26, 1878.

IV.—*Defective cartridges.*

First fire.—Decided escape of gas.

Second fire.—Same; shell failed to extract on withdrawal of bolt. Extracted on second trial.

Third fire.—Very slight escape of gas. Gun worked freely throughout test.

V.—*Dust.*

Gun worked well throughout test.

APRIL 29, 1878.

VI.—*Rust.*

Gun badly rusted; worked well throughout test.

VII.—*Excessive charges.*

After first fire gun was examined, and front end of rib on body of breech-bolt was found broken off. This was due to the barrel being cut away too much about extractor-seat, leaving cartridge-shell unsupported at that point. An examination of shells of cartridges previously fired showed that this defect had existed from the beginning of the tests, but with the service-charge no trouble was experienced.

The gun was then withdrawn by exhibitor for correction.

Hotchkiss Magazine-Gun, No. 12.

This gun differs from No. 9 in the following particulars:

The magazine cut-off and upper cartridge-stop are omitted. A small lever, A, Fig. 6, Plate II, lying in a slot on the left side of the receiver and pivoted near its middle point, has at its upper extremity a short arm extending through the side of the receiver so as to come in contact with the surface of the breech-bolt. At its lower extremity is a sort of hook, which enters a corresponding recess in the side of the trigger. On the left side of the bolt is a groove, the bottom of which is connected with the surface of the bolt by inclined planes. When this groove is opposite the upper arm of the lever mentioned—which is the case when

the bolt is locked—the trigger is free to move. When the bolt is withdrawn, the arm riding out of the groove is pushed back, and the lower arm hooks into the side of the trigger and locks it. The accidental pulling of the trigger from the groove in the bottom of the breech-bolt is thus rendered impossible, eliminating the liability of the bolt to pull entirely out when it is withdrawn.

Since the trigger can only be pulled when the bolt is closed, the first cartridge passes the cartridge-stop and is checked by the under surface of the bolt itself. When the bolt is drawn back, this cartridge, under the impulse of the magazine-spring, is shot into the chamber, while another one moves up against the cartridge-stop.

When the trigger is pulled to fire the first cartridge, the second one passes the stop, and is in turn checked by the under surface of the bolt. When the bolt is withdrawn with the empty shell, the second cartridge is shot into the chamber, and so on. In other respects this gun is the same as No. 9.

SYNOPSIS OF TESTS.

JUNE 18, 1878.

The safety test was complied with by Mr. Sweeny, representing the gun. Time, 17 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun, 25 shots were fired, of which 22 struck the target. Three cartridges were thrown out unfired, their bullets striking against the front of the receiver, stopping for the moment the action of the breech-bolt.

As a single-loader, 45 shots were fired, of which 22 struck the target. One cartridge missed fire; exploded on first blow in Winchester repeater.

II.—*Rapidity at will.*

As a magazine-gun, 14 shots were fired. Four cartridges remained in the magazine.

As a single-loader, 21 shots were fired.

III.—*Endurance.*

Gun worked satisfactorily throughout test.

IV.—*Defective cartridges.*

Moderate escape of gas at 1st and 2d rounds; none at 3d.

V.—*Dust.*

Gun worked satisfactorily throughout test.

VI.—*Rust.*

Gun badly rusted. Bolt was started by tapping on it with handle of screw-driver. Bolt pulled entirely out, due to sear not being in place.

Gun otherwise worked well throughout test.

VII.—*Excessive charges.*

Gun worked well throughout test.

This gun was not subjected to the supplementary tests, gun No. 19 being considered as representative of the system.

Hotchkiss Magazine-Gun, No. 18.

This gun differs from No. 12 only in the addition of a magazine cut-off, which is also the device for locking the breech-bolt when the piece is carried at full cock, and in the additional metal B, Fig. 2, Plate II, left at the side-cut of the receiver, with the view of preventing the accidental falling out of cartridges. By the latter change the cartridge is caused to partly enter the chamber before its head passes in the wider space at B.

The magazine cut-off, Fig. 3, Plate II, is attached to the right side of the piece. Its shaft, C, passes partly through the stock, just below the sear and in front of the magazine-tube. When the lever by which it is operated is vertical, the notched end upward, the curved side D of the shaft coincides with the upper surface of the magazine-tube, and cartridges can readily pass by it. The side E being so cut away as to admit motion of the trigger, the piece may be used as a magazine-gun. When the notched end of the lever points to the rear, the side F projects across the mouth of the tube sufficiently far to prevent the escape of cartridges. The piece may then be used as a single-loader. When the notched end points to the front, the side F comes in contact with the under side of the sear and locks the trigger, the sear being held in the groove in the bottom of the bolt; the latter is also locked. The cut-off is held in any of its positions by a small pin, G, which is forced by a spiral spring into corresponding holes in the bed, in which it turns.

SYNOPSIS OF TESTS.

AUGUST 1, 1878.

The safety test was complied with by Mr. R. T. Hare. Time, 19 seconds.

I.—*Rapidity with accuracy.*

Two attempts were made to complete this test, using the magazine. In both cases the breech-bolt was pulled entirely out in the act of ejecting the shells. This was believed to be due to too much play of the bolt in the receiver, and to the fact that the sear did not come fully up into the groove in the bottom of the bolt.

Gun withdrawn by exhibitor.

Hotchkiss Magazine-Gun, No. 19.

PLATE II.

(Does not differ from No. 18, with exception of trigger-spring.)

SYNOPSIS OF TESTS.

AUGUST 5, 1878.

The safety test was complied with by Mr. R. T. Hare. Time, 19 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun 29 shots were fired, of which 20 struck the target. 5 cartridges remained in the magazine.

As a single-loader 44 shots were fired, 26 of which struck the target.

II.—*Rapidity at will.*

As a magazine-gun 22 shots were fired. 1 cartridge remained in the magazine.

As a single-loader 28 shots were fired.

III.—*Endurance.*

Gun worked satisfactorily throughout the test.

IV.—*Defective cartridges.*

At first and second rounds moderate escape of gas; at third round none.

V.—*Dust.*

Gun worked freely throughout test.

The firing-pin spring was incidentally tested by allowing the piece to stand full-cocked for 18 hours. There was no setting of the spring.

VI.—*Rust.*

The magazine cut-off was rusted solidly in its seat; had to be started with pliers. Otherwise mechanism operated freely.

Gun worked well throughout firing.

VII.—*Excessive charges.*

Gun worked well throughout.

At last round head of shell burst just under extractor. Shell extracted readily.

SUPPLEMENTARY TESTS.

SEPTEMBER 4, 1878.

Mean time of firing 20 rounds by 3 enlisted men of the armory detachment, loading from the cartridge-box, with exception of one magazine full previously loaded, 1 minute, 37 seconds.

Of the 60 cartridges fired 43 hit the target—6′ by 24′—100 yards distance; 17 of these hit the figure of a man at the center of the target. The others were grouped well around it.

SEPTEMBER 5, 1878.

I.—*Dust.*

Slight escape of gas at firing of defective cartridges.

Gun worked well throughout test.

SEPTEMBER 21, 1878.

II.—*Rust.*

Opened with comparatively little difficulty. Bolt pulled out owing to trigger not being in its seat. After little working gun operated well. At each round with heavy charges, head of shell cut through at extractor. After last round bolt opened with some difficulty. No oil was used during the test.

FINAL TEST.

SEPTEMBER 23, 1878.

Six shots were fired (5 being in the magazine and 1 in the chamber), the gun being brought each time to the shoulder.

Mean time of three trials, 8 seconds.

Six shots were fired (1 being in the chamber and the others being taken from a cartridge-box), the gun being brought to the shoulder.

Mean time of three trials, 16 seconds.

Six shots were fired from a service Springfield rifle (1 being in the chamber and the others being taken from a cartridge-box), the piece being brought to the shoulder.

Mean time of three trials, 18 seconds.

Six shots were then fired at will from the Hotchkiss gun (the magazine and chamber being loaded) in six seconds.

Remington Magazine-Gun, No. 17.

This gun belongs to that system in which a fixed chamber is closed by a bolt, by direct action, and in which the lock is concealed.

The receiver, shown in Fig. 1, Plate III, is cut through at the rear for the breech-bolt, and at the side for the handle when the bolt is locked.

The breech-bolt is composed of three parts, viz: The body or locking-tube, A, Fig. 2; the cocking-piece, B, Fig. 3; and that (C, Fig. 4) which serves to connect the other two.

The extractor, Fig. 1, lies in a groove just in front of the rib of the locking-tube. Its tenon, D, enters a recess in the side of the tube. The rib is bored out for a spiral spring and spindle, E and F, Fig. 1, the latter of which bears against the rear of the extractor, which is turned up nearly at right angles to its length, holding the front down on the cartridge-head. When the bolt is unlocked the extractor rides around the head of the cartridge. The ejector, Fig. 5, which is attached to the front face of the locking-tube, is pierced for the point of the firing-pin. Its upper extremity is pivoted to the bolt, while its lower is free to move to the front when struck by the carrier-lever G, Fig. 1, when the bolt is withdrawn. In that case the extractor pulls on the upper side of the cartridge, while the under side is struck by the ejector. The effect is to throw the shell clear of the gun.

The cocking-piece is terminated at front by the firing-pin, Fig. 6, secured to it by a small pin at right angles to its axis. It is hollowed out for the firing-pin spring, which bears on the rear of the firing-pin at front, and at rear on a screw at right angles to the axis of the spring, through the part C of the bolt. The cocking-piece is provided with half and full-cock notches. A projection, H, on the cocking-piece enters a recess, I, on the rear of the locking-tube. The form of this projection

and its corresponding recess is such as to cam back the cocking-piece when the bolt is unlocked, far enough to permit the half-cock notch to pass beyond the sear, at the same time withdrawing the point of the firing-pin within the face of the bolt. The piece may be full-cocked by pulling the cocking-piece to the rear by the button with which it is terminated, or by drawing back the bolt and then returning it to its locking position. The bolt is prevented from being unlocked at either half or full cock by the point of the spindle in the axis of the handle entering the recess J in the cocking-piece. The spindle is held down by a spiral spring which gets its bearing on the screw K.

The magazine is in the tip-stock. The carrier is pivoted on a strong screw through the side of the receiver. Its lever works in a groove in the bottom of the locking-tube. When the bolt is withdrawn the front end of the groove strikes on the lever and tips the carrier up in a position oblique to the axis of the bore, bringing the point of the cartridge opposite the center of the chamber. The carrier is held in this position by the catch L, which springs over a pin on the inner surface of the receiver. When the bolt is closed its front presses against the catch and releases it, while the rear end of the groove in the bottom of the locking-tube strikes the carrier-lever and causes the carrier to descend opposite the mouth of the magazine. A magazine cartridge-stop, Fig. 7, is located on the left side of the receiver. One extremity partly covers the mouth of the magazine, while the other projects through the side of the receiver so as to come in contact with the bolt. A flat spring, Fig. 8, holds it in place. When the bolt is locked the end of the stop within the receiver enters the groove in the bottom of the bolt, as seen in Fig. 9. When the bolt is unlocked the side of the groove presses down on this end, and the stop moves downward, as in Fig. 10, permitting a cartridge to come out of the magazine on the carrier. The stop is so constructed that a projection on its upper side descends just in front of the rim of the cartridge as the lower part falls in rear of it, so that the escape of a second cartridge is prevented. When the bolt has been withdrawn the spring returns the stop to its first position. A magazine cut-off is provided which works in connection with the cartridge-stop. A projecting arm of the cut-off may be made to enter a recess, M, in the upper extremity of the stop and hold the latter clear from the operation of the bolt.

The magazine is loaded from below, and in any position of the bolt.

As a magazine-gun, 3 motions are necessary to operate it, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

This gun carries 8 cartridges in the magazine and 1 in the chamber.

SYNOPSIS OF TESTS.

JULY 9, 1878.

The safety-test was complied with by Mr. J. Keene, representing the arm. Time, 13 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun 34 shots were fired, of which 20 struck the target; 2 cartridges remained in the magazine; 2 cartridges missed fire; 1

exploded on second blow; the other failed on second and third trials; exploded on first blow in Springfield rifle.

As a single-loader 44 shots were fired, of which 17 struck the target; 1 cartridge missed fire; exploded on second blow.

II.—*Rapidity at will.*

As a magazine-gun 10 shots were fired. Eight cartridges remained in the magazine.

As a single-loader 24 shots were fired. One cartridge remained in the chamber. The exhibitor stated that the missfires were due to the blunt point of the firing-pin. Permission was granted him by the Board to sharpen it.

III.—*Endurance.*

One cartridge missed fire on 4 blows; exploded on first blow in Springfield rifle; 1 cartridge missed fire, but exploded on second trial.

Otherwise gun worked smoothly throughout.

IV.—*Defective cartridges.*

Free escape of gas through the gas-vent at each round. At last round the head of the shell was burst underneath the gas-escape.

V.—*Dust.*

After the first dusting it was found that cartridges would not feed from the magazine. This was due to the fact that dust had so entered as to prevent the cut-off being moved out of the way by the bolt on closing.

The piece worked satisfactorily as a single-loader. After the second dusting the same trouble with the cut-off was manifest.

Two cartridges missed fire on 3 blows; exploded on first blow in Springfield rifle.

Mr. Keene, agent for the gun, stated that by a slight filing away of surplus metal between two shoulders on the cut-off, in order to make room for dust, the defect observed would be remedied. The Board permitted this to be done, when the dust test was repeated. The gun worked well, with the exception that one cartridge did not feed up until the third trial.

VI.—*Rust.*

Guns worked well throughout.

VII.—*Excessive charges.*

Shell burst underneath gas-escape at each round. Otherwise gun worked satisfactorily.

SUPPLEMENTARY TESTS.

SEPTEMBER 4, 1878.

Mean time of firing 20 rounds by 3 enlisted men of the armory detachment, loading from the cartridge-box, with the exception of one magazine full previously loaded, 2 minutes 29 seconds.

Difficulty was experienced in getting the cartridges to feed from the

magazine, the marksmen being constantly compelled to move the cartridge-stop from its mouth.

Of the 60 cartridges fired 47 hit the target, 6′ by 24′, 100 yards distance; 15 hit the figure of a man at the center of target; the others were near it.

SEPTEMBER 17, 1878.

I.—*Dust.*

Decided escape of gas at firing of all defective cartridges. Gun worked rather stiffly. The cartridge-stop had to be pushed back by the fingers, the cut-off not operating it, before the magazine could be loaded.

SEPTEMBER 21, 1878.

II.—*Rust.*

Opened with comparative ease. Firing-pin was so rusty that mainspring would not throw it forward until it had been moved back and forth many times. Rust on end of trigger-sear and on full-cock notch prevented pulling off of the trigger without use of a rope. Cartridges did not feed up from magazine. After each round with heavy charges shell was cut through at extractor. The head in three cases was nearly cut off, due to the rotating of the extractor. Heads of two shells blew off; shells were removed by means of headless shell-extractor. No oil was used during test.

Sharps Rifle Company's Magazine-Gun, No. 3.

This gun belongs to that system in which a fixed chamber is closed by a bolt, by direct action, and in which the lock is concealed.

The receiver, shown in Fig. 1, Plate V, has a slot in its upper surface for the purpose of loading the chamber or filling the magazine. It is bored through at rear for the reception of the breech-bolt, which is composed of two principal parts, viz: The body and the locking-tube, Figs. 2 and 3. The bolt is locked by lugs, A, on the locking-tube, turning in corresponding cuts in the receiver. The bolt carries on its upper surface the extractor, Fig. 1, which is of the ordinary spring-hook pattern, and in its axis the firing-pin, which extends the whole length of the bolt. The spiral form of the face, B, of the locking-tube, and of the shoulder, C, of the bolt, is such as to cam the bolt up against the head of the cartridge when the bolt is locked.

On the rear face of the locking-tube are two spiral surfaces, F, which bear against corresponding surfaces, G, of the firing-pin. The unlocking of the bolt cams back the firing-pin until the point H, Fig. 1, passes beyond the nose I, of the sear. When the handle is turned down to lock the bolt, the firing-pin spring is compressed between the shoulders J, on the pin, and the nut K, on the extreme rear of the bolt. On withdrawing the nose of the sear, the firing-pin, under the influence of its spring, moves forward and explodes the cartridge.

The shell is ejected by the ejector-pin L, Fig. 1, which strikes against the lever M, Fig. 1, of the carrier, when the bolt is withdrawn, and is driven forward against the lower side of the head of the shell, while the extractor is pulling on the upper. The firing-pin spring and rear of bolt are protected by a thin shell, N. The bolt is prevented from being drawn completely out of the receiver by the lever of the carrier

and by a key striking on a shoulder on the upper surface of the extractor.

The magazine is in the tip-stock. The carrier is shown at O, Fig. 1. When the breech-bolt is withdrawn the projection P, in which the ejector-pin is situated, strikes the lever M, of the carrier, tipping the latter up in a position oblique to the axis of the bore, bringing the point of the cartridge nearly opposite the center of the chamber. The carrier is held in this position by the pin and spring shown at Q. When the bolt is closed the cartridge is driven in the chamber, while the projection R, on the bolt, strikes the lever, causing the front of the carrier to descend opposite the mouth of the magazine to receive another cartridge.

The carrier is of such thickness at its front as not to uncover the magazine-tube completely when the former rises. Cartridges are thus prevented from escaping from the magazine except when the carrier is in position to receive them. No magazine cut-off is applied to this gun; consequently, it can only be used as a single-loader when the magazine is empty. No wiping-rod is provided.

As a magazine-gun, 3 motions are necessary to operate it, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

This gun carries 9 cartridges in the magazine, 1 in the carrier, and 1 in the chamber.

SYNOPSIS OF TESTS.

APRIL 9, 1878.

The safety-test was complied with by Mr. Borchardt, representing the gun. Time, 15 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun, 20 shots were fired, of which 18 struck the target; 7 cartridges remained in the magazine. 1 cartridge was forced in obliquely, the bullet striking the counter-bore and checking the breech-bolt.

As a single-loader, 17 shots were fired, of which 15 struck the target. 1 shell failed to extract; 1 cartridge missed fire, due to the fact that the trigger was pulled before the bolt was locked. Great effort was necessary to draw back the breech-bolt, owing to the expansion of the copper shells.

II.—*Rapidity at will.*

As a magazine-gun, 16 shots were fired; 3 cartridges remained in the magazine. 2 cartridges missed fire from the cause above stated; 1 bullet was upset by striking against the counter-bore.

As a single-loader, 12 shots were fired; 1 shell failed to extract; the next cartridge was thrown out unfired, due to inability to enter chamber, the shell being still in;

The bolt was blocked and progress checked.

III.—*Endurance.*

During the first 50 rounds, 5 shells failed to extract. Cartridges in each case were rammed up against the shell in the chamber, checking the motion of the bolt. The exhibitor stated that in preparing his gun the

Union Metallic Cartridge Company's cartridges had been used for trial, and that the gun worked satisfactorily with them. Some of this manufacture were then obtained, when it was found that they gauged so irregularly in the diameter of the head that but few would enter the magazine-tube. 13, however, were fired. 20 Lowell cartridges were then fired; they worked satisfactorily. The second 50 was completed with the service-cartridge. Shortly after beginning the third 50, 2 shells failed to extract. The exhibitor proposed a slight filing of the extractor, to which the Board assented. It was found afterward that it did not extract at all. At the end of the 125th shot the Board discontinued the test for further correction of the extractor.

APRIL 10, 1878.

Seventy-five rounds were fired. The cartridges were Frankford arsenal manufacture. They, as well as the copper-case cartridges previously fired, had been in the Metcalfe blocks until they had become much corroded; they stuck in the chamber, requiring great effort to withdraw them. 17 shells failed to extract. 1 cartridge jarred partly out of the magazine into the carrier, checking the action of the bolt. The exhibitor then asked for and obtained permission to withdraw the gun.

Sharps Rifle Company's Magazine-Gun, No. 5.

(Differs from No. 3 only in the form of the extractor.)

APRIL 15, 1878.

Safety-test complied with by Mr. Borchardt. Time, 27 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun 18 shots were fired; all struck the target. 1 cartridge missed fire, due to the fact that the trigger was pulled before the bolt was fully locked. 1 cartridge remained in the magazine. 2 cartridges were not forced fully back into the carrier by the magazine-spring; the carrier was prevented from rising and the action of the breech-bolt checked.

As a single-loader, 26 shots were fired; all struck the target. Bolt worked with great difficulty throughout the test.

The cartridges were the copper-case, just received from Frankford arsenal.

II.—*Rapidity at will.*

As a magazine-gun, 10 shots were fired. Ten cartridges remained in the magazine.

As a single-loader, 12 shots were fired. One cartridge remained in the chamber. One cartridge was thrown out unfired, due to the cause stated under test I. The bolt had to be withdrawn by striking its handle against a table.

III.—*Endurance.*

Thirty-six shots were fired, the bolt working with great difficulty. The exhibitor then asked for and obtained permission to withdraw the gun.

Sharps Rifle Company's Magazine-Gun, No. 8.

(Differs from No. 5 in having a projection, D [Plate V], on the extractor, which, by working in a spiral groove, E, in that portion of breech-bolt to which the handle is attached, cams back the extractor as the bolt is unlocked, starting the empty shell before the withdrawal of the bolt begins.)

April 22, 1878.

Safety test was complied with by Mr. Gunn, marksman at the Sharps armory. Time, 15 seconds.

One cartridge was thrown out unfired, due to the trigger being pulled before the bolt was fully locked. The exhibitor, desiring to show that this time could be diminished, made two attempts. The first was completed in 22 seconds, and the second in 16 seconds. In each case time was lost by cartridge striking on counterbore, stopping the breech-bolt.

I.—*Rapidity with accuracy.*

As a magazine-gun, 27 shots were fired; 24 struck the target; 6 car tridges remained in the magazine.

As a single-loader, 41 shots were fired, of which 33 struck the target. In addition, 1 cartridge was thrown out unfired, due to cause already stated.

II.—*Rapidity at will.*

As a magazine-gun, 21 shots were fired; 4 cartridges remained in the magazine.

As a single-loader, 26 shots were fired.

III.—*Endurance.*

Gun worked satisfactorily throughout the test.

IV.—*Defective cartridges.*

At first fire, moderate escape of gas; paper somewhat torn. At second fire, decided escape of gas; paper much torn. At third fire, no escape of any moment. Breech mechanism somewhat fouled. Gun worked well at close of test.

V.—*Dust.*

Gun worked well throughout test.

April 25, 1878.

VI.—*Rust.*

The gun having been dipped in sal-ammoniac and exposed the prescribed period, was examined and found to be badly rusted. The breech-bolt worked freely during the firing.

VII.—*Excessive charges.*

Gun worked well throughout test. The gun was then cleaned and set aside for further action of the board.

SUPPLEMENTARY TEST.

SEPTEMBER 4, 1878.

Mean time of firing 20 rounds by 3 enlisted men of the armory detachment, loading from the cartridge-box, with the exception of one magazine full, previously loaded, 2 minutes, 34 seconds.

Of the 60 cartridges fired 38 hit the target—6′ by 24′—100 yards distance; 11 hit the figure of a man at center of target; the others were near it.

SEPTEMBER 17, 1878.

I.—*Dust.*

Considerable escape of gas at firing of defective cartridges. After second dusting extractor failed to draw one shell on first trial. Some little difficulty was experienced in working the gun. Cartridges did not feed perfectly owing to sticking of the cartridge-follower.

SEPTEMBER 21, 1878.

II.—*Rust.*

Could not be opened without pounding on bolt with lead hammer. The bolt had to be driven back and forth with the hammer after each round. No oil was used during the test.

Franklin Magazine-Gun, No. 1.

This gun belongs to that system in which a fixed chamber is closed by a bolt, by direct action, and in which the lock is concealed.

The receiver, Figs. 1 and 3, Plate VI, has a vertical slot cut entirely through it for the purpose of receiving cartridges from above and affording egress to the empty shells below. It has also a longitudinal slot through which the handle on the breech-bolt slides, with a side cut at the front end of the slot for the reception of the handle when the bolt is locked.

The breech-bolt, Fig. 6, is composed of three parts, viz: the locking-tube A, the bolt-head B, and the cocking-piece C. To the latter of these the firing-pin, Fig. 8, which extends the whole length of the breech-bolt, is secured by a screw. The bolt-head, which supports the cartridge at the instant of fire, is secured to the locking-tube by a pin at right angles to its axis. The firing-pin spring, which is held between the shoulder on the front of the firing-pin and that at the bottom of the locking-tube, serves by its tension to hold in contact the locking-tube and cocking-piece.

By means of the spiral surfaces of the projection D, Fig. 8, on the cocking-piece, and a corresponding recess on the locking-tube, the cocking-piece is cammed back, withdrawing the point of the firing-pin within the face of the bolt-head, when the piece is unlocked. Accidental explosions are thus avoided in closing the bolt. The form of the cut in the receiver at E, Fig. 1, is such as to cam back the handle, and with it the bolt, during the unlocking, starting the empty shell. This is a necessary feature of all bolt-guns which are intended to fire copper-case cartridges.

The breech-bolt is prevented from being pulled completely out by the nose of the sear F, Fig. 2, striking on the bolt-head.

The magazine, which is a metallic tube, lies on top of the barrel. The magazine stop-spring is fastened at its rear to the lever G, Fig. 1. Its front is inclined to the axis of the receiver as shown at L, Fig. 5.

When the handle is turned so as to unlock the breech-bolt, a lever, H, Figs. 4 and 10, one extremity of which enters the groove I, Fig. 6, while the other is connected with the magazine stop-spring and its lever G, Fig. 1, is so moved as to cause the stop-spring to move forward, when its inclined front springs through an opening in the side of the receiver and partially covers the mouth of the magazine, preventing escape of cartridges. When the breech-bolt is returned to its locking position the stop-spring is returned to its first position by means of the spring J, Fig. 1, operating its lever; at the same time the inclined face of the stop-spring bearing on the side of the cut in the receiver is pressed out of the way, and a cartridge issues from the magazine into the space above the breech-bolt.

It follows, therefore, that a cartridge always occupies the space above the breech-bolt when the piece is locked, provided the magazine has been previously filled. When the bolt is withdrawn this cartridge, under the influence of gravity alone, falls into a position in line with the axis of the bore. The bullet is supported by a shelf in rear of the chamber.

The base of the cartridge is prevented from falling below the line of the axis of the bore by the shape of the slot in the receiver, which is only wide enough for the shell to fall through when its head is behind the extractor. This condition only obtains when the shell is being withdrawn.

When the bolt is returned the cartridge is forced into the chamber and another one enters the space above the breech-bolt.

A lid covers the opening at top of the receiver.

A catch on the lever H, Fig. 4, serves to keep the lid closed except when the breech-bolt is unlocked. If the lid be raised during that time, a shoulder, M, Fig. 1, on its interior bearing against the lever H, prevents the stop-spring returning to its original position. The lid remaining open, the piece may be loaded and fired as a single-loader.

No ejector is required with this gun, gravity again being called on to effect the fall of the empty shell through the opening K, Fig. 3, to the ground. As a magazine-gun, 3 motions are necessary to operate, viz: opened, closed, fired. As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

This gun carries 10 cartridges in the magazine, 1 in the space above the breech-bolt, and 1 in the chamber.

SYNOPSIS OF TESTS.

APRIL 4, 1878.

The safety-test was complied with by Mr. Whitney, representing the arm, the magazine being filled before commencing the test. Time, 27 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun, 21 shots were fired, of which 17 struck the target. 7 cartridges remained in the magazine. 2 cartridges fell through the opening to the ground unfired, first catching and holding the breech-bolt.

As a single-loader, 29 shots were fired, of which 27 struck the target.

At the end of this test the marksman appeared much fatigued from holding a gun weighted with a magazine parallel to the barrel; his hand was wounded by the sharp corners on the lid, as was also Mr. Whitney's after the safety test.

II.—*Rapidity at will.*

As a magazine-gun, 18 shots were fired; 2 cartridges remained in the magazine.

As a single-loader, 21 shots were fired.

III.—*Endurance.*

At the end of 50 rounds shoulder on lid showed considerable wear, as did also the side of the breech-bolt handle. One shell failed to extract; several cartridges fell through to the ground before it was discovered; the shell was then driven out with a ramrod. At the end of 100 rounds the wear of lid was much increased. Bolt and lid worked stiffly. At end of 150 rounds the same trouble was manifest. At end of 200 rounds worked with great difficulty. Pivot-screw to lid-catch was found partly unscrewed. At end of 250 rounds the front and rear faces of breech-bolt handle showed much wear. Bolt worked exceedingly hard. At end of 270 rounds bolt worked with such great difficulty as to practically render the gun unserviceable. It being near six o'clock the test was suspended for the day.

Gun withdrawn without further test.

Ward-Burton Magazine-Gun, No. 2.

(Made at the National Armory in 1873.)

This gun belongs to that system in which a fixed chamber is closed by a bolt, by direct action, and in which the lock is concealed.

The breech-bolt is essentially a tube closed at the rear by the solid portion of which the handle forms a part, Fig. 2, Plate VII, and terminated at front by a bolt-head, Fig. 3, the top of which extends the whole length of the breech-bolt. The bolt-head carries the extractor, which is of the ordinary spring-hook pattern, and supports the cartridge at the instant of fire. The breech-bolt has a slot, A, on its lower surface, extending about two-thirds its length, parallel with its axis; at the rear the slot turns at right angles to the axis and extends about one-quarter the way around the tube. This slot receives the sear.

The firing-pin, Fig. 4, is hollowed out at its rear end for the reception of the firing-pin spring. On the pin is a cam, B, which, by bearing on an incline, C, on the bolt-head, retracts the pin, preventing it from coming in contact with the cartridge unless the piece be locked. On the rear of the pin is also a lug, D, which, fitting in a groove on the inner surface of the breech-bolt, compels the pin to rotate when the breech-bolt handle is turned, thus causing the cam on the pin to operate. The ejector, E, passes through the bolt-head below the firing-pin. The rear end of the ejector is struck by the sear when the breech-bolt is withdrawn, and driven against the lower portion of the head of the cartridge, while the extractor is pulling on the upper. The combined effect is to

throw out the empty shell. The receiver has a female-screw-thread on its inner rear surface, alternate sixths of which are cut away. The breech-bolt has a corresponding thread, F, Fig. 2, cut away in a similar manner. The breech-bolt is locked, after being pushed forward to its seat, by simply turning down the handle when the portion of the thread remaining on the bolt enters that remaining in the receiver. The thread being right-handed forces the bolt well up to the base of the cartridge, when the piece is locked; the reverse operation starts the empty shell, when it may be easily withdrawn.

The piece is cocked by withdrawing the breech-bolt and then returning it to position. When withdrawn the end of the sear passes over the shoulder, G, on the firing-pin. When the bolt is closed the firing-pin, held back by the sear, compresses the firing-pin spring. When the piece is cocked the end of the sear is in the groove A, in the breech-bolt. By pressing on the trigger the sear is lifted from the groove, and the firing-pin, impelled by its spring, explodes the cartridge.

The magazine-tube is in the tip-stock.

The carrier is shown at H, Fig. 1. When the breech-bolt is withdrawn the front end of the slot in its lower surface strikes on the lever I of the carrier, tipping the latter up in a position oblique to the axis of the bore. The point of the cartridge is thus brought opposite the center of the chamber. The carrier is held in position by a spring. When the bolt is closed the cartridge is driven into the chamber while the rear end of the slot in the breech-bolt strikes against the lever, causing the front of the carrier to descend opposite the mouth of the magazine. As the carrier descends its lower front end strikes a stop-spring, J, Fig. 1—whose function is to prevent the cartridges escaping from the tube—presses it back, and permits one cartridge to enter.

The magazine is loaded from below by first withdrawing the breech-bolt so as to lift the carrier from the end of the magazine.

A magazine cut-off enables the piece to be used as a single-loader.

As a magazine-gun, 3 motions are required to operate it, viz: opened, closed, fired.

As a single-loader, 4 motions are required, viz: opened, loaded, closed, fired.

This gun carries 7 cartridges in the magazine and 1 in the chamber.

SYNOPSIS OF TESTS.

APRIL 8, 1878.

Safety and rapidity test.

An attempt was made to comply with this test, but after two shots the breech-bolt refused to open. After some delay it was opened and an examination made, but the cause of the difficulty could not be ascertained. The test was resumed when it was discovered that the magazine stop-spring failed to prevent the cartridges from slipping partially out below the carrier, which could not then descend into position. The gun was dismounted and examined and all parts found to be sound. On being assembled it was again tried but failed not only from the cause above stated, but from cartridges being forced in obliquely to the axis of the barrel, causing them to bind and prevent the breech-block being closed. Further tests were then discontinued and the gun put in the hands of the maker, who pronounced it complete as originally made.

APRIL 9, 1878.

This gun, tried with Union Metallic Cartridge Company's cartridges, failed to operate precisely as before stated. It was then withdrawn.

Burton Magazine-Gun, No. 11.

In principle this gun does not differ from the Ward-Burton No. 2, already described. The points of difference in construction are as follows: The joint between the body of the bolt and its head is transferred in this gun to the rear, so that the body of the bolt, Fig. 2, Plate VIII, takes the place of the head, while the rear portion, Fig. 3, serves simply to lock it. As the body of the bolt does not rotate, the sear-bolt slot at right angles to its axis is dispensed with, giving, it is claimed, a stronger bolt.

The extractor A, Fig. 1, though called a lever extractor, is a spring hook pinned to the bolt near its front. The rear of the extractor is thickened so as to bear against the cam B, on the firing-pin, which prevents the descent of its rear with the corresponding rise of its front. In withdrawing a shell the spring can only be from the front portion alone. The trigger-spring C serves also to hold the carrier in place. The carrier is composed of two principal parts, D and E, separated at front by a flat spring, F. The lower portion, which is pivoted at its rear to the upper, has on its front a sort of finger, G, which may be made to pass through a slot in the upper portion so as to project partly across the mouth of the magazine, cutting off the escape of cartridges by simply turning a set-screw, H, in rear of the pivot. The motions are the same as in Ward-Burton No. 2.

This gun carries 8 cartridges in the magazine and 1 in the chamber.

SYNOPSIS OF TESTS.

JUNE 20, 1878.

The safety test was complied with by Mr. R. T. Hare, armory marksman. Time, 28 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun 29 shots were fired, of which 18 struck the target; 5 cartridges remained in the magazine.

As a single-loader 33 shots were fired, of which 27 struck the target.

II.—*Rapidity at will.*

As a magazine-gun 16 shots were fired; 2 cartridges remained in the magazine.

As a single-loader, 18 shots were fired.

During these tests the carrier failed twice to come fully up with cartridges, miss-fires being the result.

The bullets of 3 cartridges struck against the rear of the chamber, stopping the breech-bolt.

III.—*Endurance.*

Ten rounds were fired. It was found that the carrier would not bring the cartridges up in line with the axis of the bore. The Board then discontinued the test. The exhibitor, on being notified, withdrew the gun.

Lee Magazine-Gun, No. 25.

Withdrawn before drawings and detailed description could be prepared.

It may be stated, however, that it belongs to the class of bolt-guns in which the bolt is operated by direct action and in which the lock is concealed.

The peculiarity consists in the application of a magazine, either fixed or detachable, below the receiver, just in front of the guard.

The rear bottom portion of the receiver is cut away in order that the cartridges may enter from below. The latter are fed up by springs at the bottom of the magazines, retaining their parallelism with the bolt until they come in line with the axis of the bore when they are forced by the bolt in the chamber. Each magazine carries 5 cartridges; when detachable they are cheaply made and may be thrown away after the cartridges are fired.

When the magazine is detached the gun is simply an ordinary single-loader.

The empty magazine may be removed and a full one attached with great rapidity.

As a magazine-gun 3 motions are necessary to operate it, viz: opened, closed, fired.

As a single-loader 4 motions are necessary, viz: opened, loaded, closed, fired.

This gun carries 5 cartridges in the magazine and 1 in the chamber.

This gun was not tested.

BREECH-LOADING SMALL-ARMS HAVING A FIXED CHAMBER CLOSED BY A MOVABLE BREECH-BLOCK WHICH SLIDES IN THE LINE OF THE BARREL BY DIRECT ACTION, *I. E.*, BOLT-GUNS WHICH HAVE—

1.—CENTER LOCKS.

HUNT.

Hunt Magazine-Gun, No. 4.

This gun belongs to that system in which a fixed chamber is closed by a bolt, by direct action. The receiver, Figs. 1 and 2, Plate IX, has a slot in its upper surface for the purpose of loading the chamber direct when the piece is used as a single-loader; it is also bored through at rear for the reception of the breech-bolt. The latter is composed of two parts, the body and the locking-tube, which are connected by a left-hand screw-thread. The bolt is locked by two lugs, B, Figs. 6 and 7, turning in corresponding cuts in the receiver. These lugs are so shaped on their rear surfaces as to cam the bolt against the base of the cartridge during the locking. A cam, C, Fig. 6, on the inner surface of the rear end of the locking-tube forces the bolt slightly to the rear, starting the shell, during the unlocking. The opening of the joint in the breech-bolt (the thread being left-handed) during the locking aids in the camming forward of the bolt, while the closing, by drawing the forward portion to the rear, aids the starting of the shell. When the bolt is withdrawn the extractor, which is of the spring-hook pattern, pulls on

the upper side of the head of the shell while the under side strikes against the forked post A, Figs. 1 and 5. By this means the shell is thrown clear of the gun. In order to insure the ejection of the shell a quick motion of the bolt is necessary. The forked post acts also as a guide for the breech-bolt.

A slot, D, Fig. 6, in the rear of the bolt receives the nose of the hammer, allowing it to strike the firing-pin only when the piece is locked. A slide, B, Fig. 1, prevents the hammer being pulled back by catching of clothing, &c. It must be moved back before the hammer can be cocked. The magazine, which is in the tip-stock, is loaded from the side of the receiver, or from underneath, by first raising the carrier by the withdrawal of the breech-bolt. The carrier, Fig. 3, has two grooves, A, one on each side, on its inner surface. In these grooves projections A, Fig. 6, on the breech-bolt enter. As the bolt is withdrawn the projections travel in the upper horizontal portion of the grooves until they reach the inclined faces B, when, by the pressure against them, the carrier is compelled to rise, bringing a cartridge opposite the chamber. When the bolt is returned, the projections travel in the lower horizontal portion of the grooves until they reach the inclined faces C, when the carrier descends opposite the mouth of the magazine to receive another cartridge. In rising, the carrier never completely uncovers the magazine, so that cartridges cannot escape until it is in position to receive them. No magazine cut-off is provided.

As a magazine-gun 4 motions are necessary to operate it, viz: cocked, opened, closed, fired.

As a single-loader 5 motions are necessary, viz: cocked, opened, loaded, closed, fired. The gun presented, cal. 0''.44, carries 13 cartridges in the magazine, 1 in the carrier, and 1 in the chamber.

This gun not being of the prescribed caliber, was not tested by the Board.

BREECH-LOADING SMALL-ARMS HAVING A FIXED CHAMBER CLOSED BY A MOVABLE BREECH-BLOCK, WHICH SLIDES IN THE LINE OF THE BARREL BY INDIRECT ACTION, *I. E.*, MOVED BY LEVERS FROM—

2.—BELOW.

WINCHESTER.
BURGESS.
TIESING.

Winchester Magazine-Gun, No. 13.

This gun belongs to that system in which a fixed chamber is closed by a bolt, sliding in line with the axis of the barrel, and operated by a lever from below.

The receiver, Figs. 1 and 2, Plate X, is divided by a vertical partition, A, in two parts.

The carrier occupies the front portion, while the rear contains, with the exception of the breech-bolt lever, the mechanism necessary to operate both breech-bolt and carrier.

The breech-bolt, Figs. 3, 4, and 5, is a single piece, at the upper front end of which is the extractor (of the spring-hook pattern), pinned to it, and at its rear a mass of metal which supports, at either side, the

front end of one of two side-links, B and C, Fig. 1, which form a knuckle-joint. The rear ends of the other links bear against the rear of the receiver, giving the necessary support for the bolt in firing. The outer ends of the links are pivoted to the bolt and receiver, but the construction is such that no strain comes on the pivots. A groove, D, Fig. 1, on the inside of each rear link, receives the end of a strong pin on the breech-bolt lever. Motion of the lever consequently produces a corresponding motion of the links, and through them of the bolt.

The firing-pin extends the whole length of the receiver. Its point is retracted within the face of the bolt, when the bolt is drawn back, by a small lever, E, Fig. 1, one end of which enters a recess in the pin, while the other strikes against the pin F, Fig. 2, causing the lever to rotate about the pivot through the front end of the links attached to the breech-bolt. A flat spring—not shown in the figures—bearing against the surface of the breech-bolt lever holds it in place.

The hammer is cocked by the end of the firing-pin when the breech-bolt lever is thrown forward.

The piece is fired by a center lock of the usual pattern. A safety device or sear prevents the pulling of the trigger when the piece is unlocked. When the breech-bolt lever is closed, it strikes the pin K projecting from the under side of the sear, and removes it from the safety position. Shells are ejected by the carrier, which, rising as they are being withdrawn, strikes them at a distance of about one-third their length from the rear, and rotates them about the extractor, throwing them clear of the gun.

The magazine is in the tip-stock. It is loaded through a gate in the side cover of the receiver, as is also the piece when used as a single-loader. The carrier is moved at right angles to the axis of the barrel by its lever G, Figs. 1 and 2. This lever is thrown up by the shoulder H of the breech-bolt lever striking its under surface when the latter is thrown open. The carrier-lever is depressed in a similar manner when the breech-bolt lever is closed, by the latter bearing on a shoulder on its upper surface.

The spring J holds the lever and carrier in either position, Figs. 1 and 2. In rising, the carrier does not completely uncover the mouth of the magazine; cartridges cannot therefore escape below it.

No magazine cut-off is provided.

As a magazine-gun, 3 motions are necessary to operate it, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

The motions of opening and closing might perhaps be classed as a single motion, being continuous, the hand not being removed from the lever.

This gun carries 9 cartridges in the magazine, 1 in the carrier, and 1 in the chamber.

SYNOPSIS OF TESTS.

JUNE 18, 1878.

The safety test was complied with by Mr. Sweeny, representing the gun. Time, 6 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun 35 shots were fired, of which 22 struck the target Eight cartridges remained in the magazine. As a single-loader 30 shots were fired, of which 24 struck the target.

II.—*Rapidity at will.*

As a magazine-gun 28 shots were fired. Two cartridges remained in the magazine.

As a single-loader 23 shots were fired. One cartridge remained in the chamber.

III.—*Endurance.*

Gun worked well throughout test. Extractor failed to draw one shell.

IV.—*Defective cartridges.*

Decided escape of gas at first and second rounds; no escape at third round.

V.—*Dust.*

Gun worked satisfactorily throughout test.

VI.—*Rust.*

Gun worked well throughout test.

VII.—*Excessive charges.*

At first and third rounds extractor failed to draw shells till second trial.

Otherwise gun worked satisfactorily.

SUPPLEMENTARY TESTS.

SEPTEMBER 4, 1878.

Mean time of firing 20 rounds by 3 enlisted men of the armory detachment, loading from the cartridge-box, with the exception of one magazineful previously loaded, 1 minute 58 seconds. Of the 60 cartridges fired 48 hit the target, 6′ by 24′, 100 yards distance; 28 hit the figure of a man at center of the target; the others were grouped well around it.

SEPTEMBER 5, 1878.

I.—*Dust.*

Considerable escape of gas at firing of defective cartridges. Gun worked well after first dusting, except that extractor failed to draw 2 shells on first trial. After second dusting the mechanism was considerably fouled and its operation checked. After few minutes was put in sufficient order to fire. Extractor failed to draw one shell.

SEPTEMBER 21, 1878.

II.—*Rust.*

Gun was so badly rusted that it could not be operated. After attempts at getting it in working order had been abandoned it was oiled and laid aside.

Burgess Magazine-Gun, No. 22.

This gun belongs to that system in which a fixed chamber is closed by a bolt, sliding in line with the axis of the barrel, and operated by a lever from below.

The bolt, Fig. 3, Plate XI, is a single piece, the rear of which serves as a guide to its motion by sliding in grooves on the inner surface of the receiver. The bolt is locked by the interposition of the portion A, Fig. 8, of the breech-bolt lever, between its head and the rear of the receiver. The bolt-head and lever are pivoted at B. The firing-pin, which is in this portion of the lever, passes through the pivot B and prevents it moving either way. The firing-pin is retained in the lever by the screw C. The ejector D, Figs. 2 and 5, lies in a groove across the front of the bolt, just below the firing-pin hole; its rear terminates in a split spring, which, by friction against the side of an undercut groove in the side of the bolt, retains it in position.

The ejector is driven forward against the under side of the head of the cartridge, when the lever is thrown open by its rear striking against a shoulder on the inner rear surface of the receiver. The bottom opening in the receiver is closed by a plate, E, called the lever-guide; its rear is terminated by a piece, F, the tenon of which enters a corresponding mortise in the plate. An elongated hole in the tenon, through which passes the pin connecting the pieces, permits motion of the smaller part to and from the plate. A spiral spring is comprised between the two pieces. The motion of the lever in opening and closing is a sliding one, the lever bearing against the end of the part F, which serves as a fulcrum. The carrier G, Figs. 1 and 6, is pivoted on two short screws through the sides of the receiver. It is operated by a hooked projection, H, Figs. 1 and 5, on the bolt-head, which, sliding under it, supports it until the forward motion of the lever is nearly completed, when, by striking against the surfaces I, the carrier is rotated about the pivot-screws, its front descending opposite the mouth of the magazine, which is in the tip-stock. When the lever is closed, the projecting hook, passing out of the recess I, slides under the carrier, raising it to a position parallel to the axis of the barrel, when its upward motion is limited by pins projecting from the inner surfaces of the receiver. The hammer is cocked by the backward motion of the bolt when the lever is thrown forward. The piece is fired by a center-lock of the usual pattern. The magazine is loaded through a side cover in the receiver. No wiping-rod is provided, and there is no cut-off to the magazine.

As a magazine-gun, 3 motions are necessary to operate it, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

This gun carries 10 cartridges in the magazine and 1 in the chamber.

SYNOPSIS OF TESTS.

AUGUST 15, 1878.

The safety-test was complied with by Mr. F. Tiesing. One cartridge was thrown out unfired. Time, 14 seconds.

I.—*Rapidity with accuracy.*

As a magazine gun, 20 shots were fired, of which 19 struck the target; 7 cartridges remained in the magazine. The breech-bolt was twice wedged by two or more cartridges escaping from the magazine at once; 3 cartridges were thrown out unfired.

The gun was then withdrawn.

Burgess Magazine-Gun, No. 23.

Differs from No. 22 in the addition of the parts J, K, and the spring L, Fig. 1, Plate XI. The object of applying these parts was to prevent the re-descent of the carrier and the consequent feeding of two or more cartridges from the magazine, when the lever was thrown forward without first having been completely closed. The operation of these parts is as follows:

When the lever is thrown open, the rear of the carrier turns the piece J about its pivot M, depressing the piece K, as in Fig. 2. If now the lever be partially closed, the carrier will rise and the spring L rotate the piece J behind it. The carrier cannot descend again until the lever has been closed, when the shoulder N, Fig. 8, forces up the part K, which in turn rotates the piece J to the position shown in Fig. 1, when the carrier is free to operate.

SYNOPSIS OF TESTS.

AUGUST 31, 1878.

The safety-test was complied with by Mr. F. Tiesing, agent of the Whitney Arms Company. One cartridge was thrown out unfired. Time, 11 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun, 31 shots were fired, of which 18 struck the target; 6 cartridges remained in the magazine.

As a single-loader, 27 shots were fired, of which 22 struck the target; 1 cartridge was thrown out unfired.

II.—*Rapidity at will.*

As a magazine-gun, 19 shots were fired; 1 cartridge was thrown out unfired; 1 cartridge missed fire, due to the lever not being fully closed; 8 cartridges remained in the magazine.

As a single-loader, 18 shots were fired; 1 cartridge remained in the chamber.

III.—*Endurance.*

One hundred and two shots were fired, when the bottom lever-guide was found broken off. Examination showed defect in the material.

SEPTEMBER 2, 1878.

The gun having been put in order by the substitution of a new lever-guide, the endurance-test was resumed.

III.—*Endurance.*

At the end of 350 rounds the ejector was so fouled that the magazine-spring, acting through the medium of the cartridge issuing from the magazine, could not return the ejector to its seat; the result was that the cartridge being partly out of the magazine prevented the carrier from rising, and, consequently, the closing of the lever. The Board permitted Mr. Tiesing to take the gun apart and oil the ejector. The firing was then resumed. During the next 100 rounds the extractor failed to draw 7 shells. Mr. Tiesing was then permitted to remove the extractor to ascertain the cause. After returning it the firing was again resumed. During the last 50 rounds 3 shells failed to extract.

IV.—*Defective cartridges.*

Slight escape of gas at first and second rounds; none at third.

V.—*Dust.*

After the first dusting, 9 shells of the 20 cartridges fired failed to extract. Most of them extracted on second trial.

After second dusting, 13 shells failed to extract. The majority of them had to be driven out with a ramrod.

VI.—*Rust.*

Lever could not be closed when last cartridge was fed from magazine, owing to the front of the carrier not camming back the cartridge-follower which projected over it.

Otherwise, gun worked fairly.

VII.—*Excessive charges.*

Cover, or upper breech-bolt guide, blew off at last round, disabling gun.

SEPTEMBER 14, 1878.

A new cover, vented to permit free escape of gas, having been provided, the seventh test was repeated.

VII.—*Excessive charges.*

Gun worked well except that after last round it was opened with considerable difficulty.

SUPPLEMENTARY TESTS.

SEPTEMBER 17, 1878.

I.—*Dust.*

Considerable escape of gas at firing of defective cartridges. Some little difficulty was experienced in feeding cartridges from the magazine after first dusting, owing to sticking of the cartridge-follower. This sticking was increased after second dusting; the gun had to be held nearly vertically in order that the cartridges might feed out through the influence of gravity.

Gun worked rather stiffly.

SEPTEMBER 21, 1878.

II.—*Rust.*

Lever had to be pried open with heavy screw-driver. Gun worked with difficulty until the parts had been loosened by frequent working. At first heavy charge the top cover or bolt-guide blew up, binding and wedging the piece so as to render it unserviceable.

No oil was used during the test.

Tiesing Magazine-Gun, No. 21.

This gun belongs to that system in which a fixed chamber is closed by a bolt sliding in line with the axis of the barrel and operated by a lever from below.

The breech-bolt A, Fig. 1, Plate XII, is a single piece, to which links B are hinged at either side. These links are in turn connected by a knuckle-joint, with others, C, hinged to the receiver. These links support the bolt when closed, as in firing. The axes of the pivots about which the links rotate are in line with the axis of the bore. The construction is such that no strain comes on the pivots. The upper rear ends of the forward links lock in the receiver, giving additional support to the bolt. A groove on the inner surface of each rear link receives the end of a pin in the breech-bolt lever; motion of the lever is consequently accompanied by a corresponding motion of the links and, through them, of the bolt.

The hammer is cocked by the end of the firing-pin when the lever is thrown open.

The piece is fired by a center-lock of the usual pattern. The magazine, which is in the tip-stock, is loaded through a gate in the side cover of the receiver. The carrier, D, Fig. 1, is pivoted at the rear of the receiver. The upper end of the breech-bolt lever is slotted as in Fig. 3. This slot receives the rear portion of the carrier. When the lever is thrown open the bottom of the slot strikes the arm C, and rotates the carrier about its hinge, bringing its front opposite the mouth of the magazine. The reverse motion of the lever raises the carrier until its upper surface is parallel to the axis of the bore.

No wiping-rod is provided with this gun, and there is no magazine cut-off.

As a magazine-gun, 3 motions are necessary to operate it, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

This gun carries 9 cartridges in the magazine and 1 in the chamber.

SYNOPSIS OF TESTS.

AUGUST 15, 1878.

The safety-test was complied with by Mr. F. W. Tiesing. One cartridge was thrown out unfired. Time, 9 seconds.

I.—*Rapidity with accuracy.*

During this test, 3 cartridges escaped from the magazine and wedged over the carrier, in the receiver, in such a manner as to stop the operation of the breech-bolt.

In a second trial, 21 cartridges were fired, of which 14 struck the target; 7 cartridges remained in the magazine. The same difficulty occurred as in the first trial.

The exhibitor then withdrew the gun.

BREECH-LOADING SMALL-ARMS HAVING A FIXED CHAMBER CLOSED BY A MOVABLE BREECH-BLOCK, SLIDING AND ROTATING, AND MOVED BY A LEVER FROM BELOW.

CHAFFEE. BUFFINGTON.

Chaffee Magazine-Gun, No. 26.

This gun belongs to that system in which a fixed chamber is closed by a movable breech-block, sliding and rotating, and operated by a lever from below. On the inner surface of the receiver are two circular guides, A, Fig. 1, Plate XIII, which enter grooves B, Fig. 4, in the breech-block and over which the breech-block slides. The block is a single piece hollowed out to receive the hammer C and the main-spring D.

At the front of the block is the firing-pin E, limited in its motion by the screw F. The breech-block is operated by the lever G. The front of the lever is hinged to the front of the breech-block; its middle is hinged to two arms which are in turn hinged to the sides of the receiver. The hammer is cocked when the breech-block lever is thrown open by the pressure of the lever hook H on the face of the hammer, which forces the latter back until the nose of the sear—which is a part of the trigger—enters the notch I. Reverse motion of the lever closes the block which is locked by the projection J, on the lever, entering the recess K, Fig. 2, in the block and in the sides of the receiver.

The extractor L, Figs. 2, 5, and 6, is not rigidly connected with the breech-block, but has a longitudinal motion along its side. It does not begin to draw the shell until the breech-block has moved to the rear nearly an inch, when a shoulder on the extractor strikes a corresponding one on the block, after which both move together. The object of the extractor projecting so far in front of the block is to support the cartridges as they leave the magazine on their way to the chamber. A shoulder, R, on the bottom of the carrier serves as an ejector. Its effect is to rotate the empty shells through the opening in the bottom of the receiver, to the ground. The magazine is in the butt-stock. At the bottom of the tube are two ratchet bars, one sliding, the other fixed. Ribs on the sides of the bars enter grooves in the sides of the tube as in Fig. 7. Springs on the under side of the bars hold them up against the cartridges. The sliding bar is operated when the lever is opened and closed by pins M and N, on the inner surface of the breech-block, striking against the hook O on the front of the bar. The operation of feeding the cartridges to the chamber is as follows:

The magazine having been loaded through the butt-plate, the lever is thrown open and each tooth of the sliding bar passes behind the head of the cartridges next in rear of it. The closing of the lever moves the ratchet forward, bringing each cartridge its own length farther to the front. The function of the fixed ratchet is simply to prevent the cartridges sliding backward after they have been carried forward by the movable bar. The carrier P, Figs. 1 and 2, closes the opening in the top of the receiver. It receives and guides the cartridge from the magazine to the chamber. The shape of the inner surface of the carrier at its front is such that the point of the cartridge as it leaves it, is opposite the center of the chamber. The extractor moving forward with the breech-block, supports the rear of the cartridge as in Fig. 2. The inclined rear surface of the carrier prevents the rear of the cartridge from rising while on its way to the chamber. When the lever is thrown open

a spring, Q, at the front of the carrier, causes its rear to descend opposite the mouth of the magazine. In this position it serves as a cartridge-stop, preventing the escape of other cartridges.

There is no cut-off to the magazine, nor can there be, each motion of the lever being accompanied with a corresponding motion of the rachet.

As a single-loader, the piece is loaded through the carrier, the rear of which is opened by depressing the front; this should be done before the lever is opened.

The trigger is locked by a set-screw when the piece is carried at full-cock.

As a magazine-gun, 3 motions are necessary to operate, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: loaded, opened, closed, fired.

This gun carries 6 cartridges in the magazine, 1 in the carrier, and 1 in the chamber.

SYNOPSIS OF TESTS.

SEPTEMBER 14, 1878.

The safety-test was complied with by Mr. R. S. Chaffee. Time, 35 seconds.

Four cartridges were thrown out unfired; one of them showed evidence of having been struck by the firing-pin.

This test was repeated, the time being 33 seconds.

Mr. Chaffee then withdrew the gun in order to perfect its mechanism.

Buffington Magazine-Gun, No. 7.

This gun belongs to that system in which a fixed chamber is closed by a movable breech-block, sliding and rotating, and operated by a lever from below.

The receiver, Fig. 1, Plate XIV, to which the barrel is attached in the usual way, has a vertical slot entirely through it for the reception of the breech-block, and two grooves, A A, at right angles to each other, on the inner surface of each side. In these grooves, the flattened ends of pivots passing through the breech-block at B and C, Fig. 3, slide. The various points of the breech-block, not in the axes of the pivots, thus describe arcs of ellipses when the block is opened or closed. The block is hollowed out to receive the hammer, mainspring, &c. The hammer, Figs. 4, 5, and 6, is slotted to receive one branch of the mainspring which abuts against a pin, D, Fig. 1. The other branch bears against a similar pin through the breech-block. The piece is locked by lugs projecting from pieces screwed to the sides of the receiver, partly across its top and entering the grooves E, Fig. 5, on the hammer, as seen in Fig. 10. The firing-pin is retracted, when the block is unlocked or the hammer cocked, by the slot F, Fig. 5, which receives the head of the pin, as in Fig. 7.

The extractor G, Fig. 1, is a bent spring hook secured at its rear to the breech-block by a pin and supported at its front by the pivot C. In order to open the block, it is necessary to draw back the hammer to a point a little beyond the full cock, and then control the motion by the lever H. Should the hammer be let down while the block is open, it is

cocked in the act of closing by the edges of the surface I, Fig. 4, striking on projections on the inner rear surface of the receiver.

The magazine is in the tip-stock. It is provided with two cartridge stop-springs, J and K, Fig. 7. The carrier, Figs. 8 and 9, is made of sheet steel brought to a spring temper. It is secured to the breech-block by the pivot C, Fig. 1; it is thrown up by the point L, Fig. 3, striking under the point M, Fig. 8, as in Fig. 7. When the breech-block is closed the carrier-block descends, its spring, M, keeping it in contact with the breech-block, bears down on the stop-spring J, and slides under the end of the magazine-tube. As it passes under the tube the inclined planes N, Fig. 9, raise the ends of a cross-piece riveted to the stop-spring K, when a cartridge is forced by the magazine-spring into the carrier.

A cut-off enables the piece to be used as a single-loader.

As a magazine-gun, 3 motions are necessary to operate, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

This gun carries 6 cartridges in the magazine and 1 in the chamber.

SYNOPSIS OF TESTS.

APRIL 22, 1878.

An attempt to comply with the safety-test was made by Major Buffington. Owing to the sticking of cartridges in the mouth of the magazine—which was contracted to prevent the escape of the cartridge-follower—only 3 shots were fired. In order to start the cartridges the butt of the gun was struck on the ground. The resulting shock broke off the magazine stop-spring, bringing the test to an end. The gun was then withdrawn for alteration.

Buffington Magazine-Gun, No. 10,

Differs from No. 7 in having a slot in the magazine-tube and a small screw in the cartridge-follower at right angles to its axis, which, entering the slot, guides the follower and prevents its escape from the tube.

APRIL 23, 1878.

Safety-test was complied with by Major Buffington. One cartridge fell to the ground unfired; cause unknown. Time, 37 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun, 20 shots were fired; 19 struck the target.

As a single-loader, 24 shots were fired; 21 struck the target. In loading, one cartridge passed below the chamber partly in the magazine. A misfire resulted. On opening the block, the cartridge fed up and was fired.

II.—*Rapidity at will.*

As a magazine-gun, 14, and as a single-loader, 13, shots were fired.

III.—*Endurance.*

Four hundred shots were fired. One cartridge missed fire on two blows; fired on first blow in Springfield rifle. Two cartridges in some manner were forced from the magazine-tube under the carrier, stopping the firing until they could be removed.

APRIL 24, 1878.

III.—*Endurance.*

Last 100 rounds were fired. Breech-system worked stiffly. Three cartridges fell out over top of block while ejecting shells. One cartridge missed fire, but exploded on second blow. One cartridge missed fire twice, but exploded on first blow in Springfield rifle.

IV.—*Defective cartridges.*

First fire.—Decided escape of gas; paper torn. *Second fire.*—Moderate escape of gas; paper soiled. *Third fire.*—No escape of gas.

V.—*Dust.*

Breech-block opened and closed with great difficulty, causing much delay. One misfire. One cartridge fell out unfired, and the empty shell, which was being ejected at the time, was returned to the chamber.

APRIL 26, 1878.

VI.—*Rust.*

The cartridge-follower was solidly rusted in the magazine; it was loosened by driving on it with the ramrod. The magazine-spring did not operate; cartridges were fed from the magazine, through the influence of gravity, by holding the gun vertically, muzzle up. The breech-system worked with great difficulty; was opened with the aid of a stick.

VII.—*Excessive charges.*

Gun worked with greatest difficulty. Extractor was found broken after last fire. The gun was then cleaned and set aside for further action of the Board.

Withdrawn.

BREECH-LOADING SMALL-ARMS HAVING A FIXED CHAMBER CLOSED BY A MOVABLE BREECH-BLOCK, WHICH ROTATES ABOUT A HORIZONTAL AXIS AT 90° TO THE AXIS OF THE BARREL, LYING ABOVE THE AXIS OF THE BARREL AND IN FRONT.

SPRINGFIELD-MILLER.

SPRINGFIELD-CLEMMONS.

Miller Magazine-Gun, No. 15.

This gun is an adaptation of a magazine to the United States service Springfield rifle.

The breech-system is too well known to need description.

The alterations are as follows:

The original receiver and breech-pin are replaced by a receiver alone the tang being solid with it. The upper rear part of the receiver gives

the bearing for the cam, while the space ordinarily filled by the breech-pin is utilized as a channel through which the cartridges are fed from the magazine in the butt-stock. The ejector-stud is replaced by one beveled on its rear as well as its front, in order that the cartridges may slip easily over it into the chamber. The magazine, Fig. 1, Plate XV, is a tube slotted through its whole length. To the upper side of the tube flat springs, A, are screwed. At the end of each spring and riveted to it is a lug, B, beveled on its rear surface; these lugs pass through holes cut in the magazine and serve to separate the cartridges.

A ratchet, C, Figs. 1 and 2, works in the slot in the magazine-tube. It is operated by the slide D, attached to the guard-plate. When the slide is drawn back the teeth of the ratchet pass in rear of the heads of the cartridges. On being returned to position each tooth moves a cartridge forward, the lugs on the springs A being pressed out of the way by the cartridges themselves.

At the front of the ratchet is a cartridge-stop, E, held up by the spring F. The stop is prevented from rising too far by the pin G. When the ratchet is withdrawn the stop-spring yields—since the cartridges cannot move backward on account of the shoulders of the lugs on the springs—the stop descends and is drawn under the first cartridge, which is then free to leave the magazine and enter the chamber, gravity being the motive force, the gun being held muzzle downward. When the ratchet is moved forward the 2d cartridge occupies the place of the 1st, the 3d of the 2d, and so on. The ratchet is prevented from entering the tube by two pins, H and G, which bear against the outer surface of the tube along the edges of the slot. It is held in contact with the tube by the spring J. The spring is kept from slipping off the bottom of the ratchet by the forks K and L. The magazine is loaded through a gate in the butt-plate. A projection, N, on the breech-block hooks over the pin O and prevents motion of the ratchet when the piece is locked.

As a magazine-gun, 5 motions are necessary to operate it, viz: cocked, opened, loaded (by operating the ratchet by the slide), closed, fired.

The same number of motions is necessary as a single-loader.

This gun carries 6 cartridges in the magazine and 1 in the chamber. The last cartridge will not feed from the magazine, however, until forced down by others when the magazine is reloaded.

JUNE 25, 1878.

The safety-test was complied with by Mr. R. T. Hare. Time, 1 minute and 2 seconds.

The Board directed that the time of emptying the magazine (6 shots) be ascertained in comparison with the time of firing the same number of shots from the gun as a single-loader.

Time in the first instance, 18 seconds; in the second, 15 seconds.

II.—*Rapidity at will.*

As a magazine-gun, 14 shots were fired; 3 cartridges remained in the magazine.

As a single-loader, 23 shots were fired.

Gun withdrawn by exhibitor.

Clemmons Magazine-Gun, No. 24.

This gun is an adaptation of a magazine to the United States Springfield rifle. The alterations are as follows:

The left side of the receiver is cut away nearly to the bottom of the well. The portion removed is replaced by a piece, A, Figs. 2 and 3, Plate XVI, the interior of which is somewhat the shape of the half cartridge. This piece is open at the rear in order to receive cartridges from the magazine. A groove is cut in the left side of the butt-stock for the magazine-tube. The groove is covered by a brass plate, B, Fig. 5. The magazine-spring and cartridge-follower are of the usual form. To the rear of the follower one end of a piece of tape is attached; the other end is connected with an ordinary clock-work by which the tape may be wound up, drawing back the follower and compressing the magazine-spring as in Fig. 1. On the inner surface of the piece attached to the receiver, is a split spring, C, Fig. 1, pivoted at its front. This spring has a thumb-piece, D, which may be locked back as in Fig. 2, by a spring-catch, E. The split-spring serves as a magazine cartridge-stop, Fig. 3. The magazine-spring having been compressed by winding up the clock-work, the magazine is filled with cartridges by backing them down from the receiver. The pawl F, Fig. 1, is then released from the ratchet G, by means of a slide and the magazine-spring bears on the column of cartridges. When the breech-block is closed it strikes the thumb-piece D, presses it back and lets in a cartridge from the magazine, as in Fig. 2. By pressing on this thumb-piece, the breech-block having been opened, sufficiently to overcome the catch E, the cartridge is thrown into the receiver; it must then be pushed into the chamber in the usual manner.

As a magazine-gun, 6 motions are necessary to operate it, viz: cocked, opened, loaded (2 motions), closed, fired.

As a single-loader, the usual 5 motions are necessary.

This gun carries 5 cartridges in the magazine, 1 opposite the receiver, and 1 in the chamber.

SYNOPSIS OF TESTS.

SEPTEMBER 2, 1878.

The safety-test was complied with by Mr. R. T. Hare. Time, 53 seconds.

Seven cartridges, carried in magazine and chamber, were fired by Mr. Clemmons in 23 seconds.

The gun was then withdrawn.

Clemmons Magazine-Gun, No. 27.

Differs from No. 24, Plate XVI, in the following particulars: The clock-work is omitted. A stop is provided to hold the cartridges against the pressure of the magazine-spring while loading; it is moved out of the way after the magazine is filled by means of a button connected with it. The stop is located near the front of the magazine.

SYNOPSIS OF TESTS.

SEPTEMBER 11, 1878.

The safety-test was complied with by Mr. C. E. Bailey. Time, 45 seconds. One cartridge was thrown out unfired.

On repeating the test, the time was reduced to 37 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun, 14 shots were fired, of which 9 struck the target. Six cartridges remained in the magazine.

As a single-loader, 39 shots were fired, of which 9 struck the target. One cartridge remained in the chamber.

II.—*Rapidity at will.*

As a magazine-gun, 8 cartridges were fired, 4 remained in the magazine.

As a single-loader, 24 cartridges were fired.

The piece attached to the receiver being only of a temporary character, Mr. Clemmons was unwilling to submit the gun to further test; it was accordingly withdrawn.

BREECH-LOADING SMALL-ARMS HAVING A FIXED CHAMBER CLOSED BY A MOVABLE BREECH-BLOCK, WHICH ROTATES ABOUT A HORIZONTAL AXIS AT 90° TO THE AXIS OF THE BARREL, LYING BELOW THE AXIS OF THE BARREL AND IN FRONT—MOVED BY A LEVER FROM BELOW.

LEWIS-RICE.

Lewis-Rice Magazine-Gun, No. 6.

This gun belongs to that system in which a fixed chamber is closed by a movable breech-block rotating about a horizontal axis at right angles to and below the axis of the barrel, and in front, and in which the lock is concealed.

The breech-block is operated by a lever, A, and is locked by a cam, B, Fig. 1, Plate XVII. The cam is held in position by the spring C, one branch of which serves as a trigger-spring. The breech-block is simply a box containing the firing-pin D, a bell-crank lever, E, one arm of which controls the motion of the firing-pin, the main-spring F, trigger-spring G, &c. The box is closed by a cover, in a slot in which is situated the extractor H, Fig. 2. In operating the lever A, so as to open the block, the point I bears against the surface J of the cam, presses it forward and unlocks the piece.

During the unlocking, the lower arm of the firing-pin lever is so moved by the nose of the cocking-lever as to cause the upper arm to retract the firing-pin. When the lever has been rotated sufficiently, the trigger-spring causes the nose of the trigger to enter the full-cock notch; at the same time the shoulder, K, of the cam rides over the point L of the trigger. The piece cannot then be fired until the cam is in its seat.

The extractor is a flat blade, turning on the same axis as the lever A, and operated by the shoulders of the slot in the cover of the breech-block, in which it lies.

The magazine is in the butt-stock. It is loaded at the side, near the rear, by first withdrawing the magazine-tube nearly its full length. When the breech-block is opened, a cartridge is forced by the magazine-spring against the cartridge-stop M, Fig. 2. As the block is closed, the stop descends, due to its arm N working in a slot on the inner surface of the receiver, and the cartridge enters the chamber. A fork, O, on the upper surface of the receiver prevents the cartridge being thrown out when the block is closed, and also guides it into the chamber. A cut-off is

situated on the left side of the receiver. It may be so set as to prevent the breech-block opening far enough to allow cartridges to feed from the magazine. The piece may then be used as a single-loader. As a magazine-gun, 3 motions are necessary to operate it, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

This gun carries 5 cartridges in the magazine and 1 in the chamber.

If the breech-block be opened, the six cartridges may be loaded directly in the magazine.

SYNOPSIS OF TESTS.

APRIL 15, 1878.

The safety-test was complied with by Mr. H. A. Lewis, presenting the gun. Time, 29 seconds.

One cartridge was thrown out unfired, the blow of the firing-pin being insufficient to explode it.

I.—*Rapidity with accuracy.*

As a magazine-gun, 15 shots were fired; 14 struck the target. Cartridges did not feed freely from the magazine, but caught in the space behind the breech-block, preventing working of the gun. About one-half the time was consumed in removing obstructions.

As a single-loader, 25 shots were fired; 23 struck the target; 8 cartridges, in addition, were thrown out unfired.

II.—*Rapidity at will.*

As a magazine-gun, 2 cartridges were fired; 2 were thrown out unfired; 4 remained in the magazine. The magazine-spring did not force the cartridges sufficiently far in to be carried forward by the breech-block. The block became wedged, bringing the test to a close.

The gun was then withdrawn by the exhibitor.

Lewis-Rice Magazine-Gun, No 14.

This gun belongs to that system in which a fixed chamber is closed by a movable breech-block, rotating about a horizontal axis at right angles to and below the axis of the barrel, and in front, and in which the lock is concealed.

The breech-block is operated by a lever, A, and is locked by a cam, B, Fig. 1, Plate XVIII; the cam is held in position by its spring, C. The breech-block is a sort of box containing the hammer, main-spring, cam-spring, &c., and to the outside of which is attached the extractor. In operating the lever so as to open the block, the point D bears against the surface E of the cam, and causes it to move forward, unlocking the block. At the same time the hammer is forced back by the pawl F, pivoted to the lever A, bearing against its shoulder, G. The shoulder H of the cam, riding over the point I of the trigger, presses it down, raising the other extremity, or sear, to the full-cock notch J. It is impossible to fire the piece until the block is locked, because the shoulder H

of the cam remains over the rear of the trigger until the cam is in its seat.

A safety device, K, turned in between the lower portion of the receiver and the trigger, prevents the pulling of the latter when the piece is carried cocked. The extractor is positive in its action. It is simply a flat blade turning on the same axis as the lever, and working in a slot in the cover of the breech-block. The magazine is in the butt-stock. It is loaded at the side, near the rear, by first withdrawing the tube nearly its whole length. When the piece is opened a cartridge is forced by the magazine-spring into the position shown in Fig. 2. It is checked by the stop L, which descends by a positive motion as the block is closed, due to an arm working in a slot on the inner surface of the receiver. A fork, M, on the upper surface of the receiver, held in position by the spring N, prevents the cartridge being thrown out as the block is closed, and also serves to guide the cartridge to the chamber.

A device at the left side of the receiver may be so set as to prevent the breech-block opening far enough to receive cartridges from the magazine. The piece may then be used as a single-loader.

As a magazine-gun, 3 motions are necessary to operate it, viz: opened, closed, fired.

As a single-loader, 4 motions are necessary, viz: opened, loaded, closed, fired.

This gun carries 5 cartridges in the magazine and 1 in the chamber. If the breech-block be opened, the 6 cartridges may be loaded directly into the magazine.

SYNOPSIS OF TESTS.

JUNE 19, 1878.

The safety-test was complied with by Mr. D. Kirkwood, maker of the gun. Time, 21 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun, 27 shots were fired, of which 22 struck the target; 3 cartridges remained in the magazine.

As a single-loader, 31 shots were fired, of which 27 struck the target.

II.—*Rapidity at will.*

As a magazine-gun, 12 shots were fired; 4 cartridges remained in the magazine.

As a single-loader, 16 shots were fired.

For some reason not thoroughly understood the gun did not work smoothly. The block stuck so that it was closed with the greatest difficulty. Bullets struck on the cartridge-stop and were much disfigured when the block was closed by force.

III.—*Endurance.*

Three hundred rounds were fired. Throughout the firing the difficulty before stated constantly occurred, though in greater degree. The locking device failed to operate. The breech-block was dismounted in the presence of the exhibitor, but the trouble could not be ascertained. All appeared to be in order as originally constructed. The sharp edge of the cartridge-stop, which sheared the bullet when the block was closed, was rounded off at the request of the exhibitor, but without much apparent benefit.

Gun withdrawn by exhibitor.

Lewis-Rice Magazine-Gun, No. 16.

(Does not differ in principle from No. 14, Plate XVIII. The changes made consist in slightly altering the form of the cartridge-stop and filing down surfaces where former trials showed too great friction.)

JULY 9, 1878.

The safety-test was complied with by Mr. H. A. Lewis. Time, 30 seconds.

The action of the breech-block was irregular, difficulty being experienced in closing it.

I.—*Rapidity with accuracy.*

As a magazine-gun, 18 shots were fired, of which 10 struck the target; 5 cartridges remained in the magazine. The breech-block caught and could not be closed. The difficulty appeared to be in the magazine-spring, which was too weak to force the cartridges forward beyond the face of the breech-block against the cartridge-stop. The result was that the upper front edge of the block was forced into the side of the cartridge and the further operation of the block checked.

Gun withdrawn by exhibitor.

Lewis-Rice Magazine-Gun, No. 20.

(Does not differ in construction from No. 16. New magazine-spring substituted.)

SYNOPSIS OF TESTS.

AUGUST 8, 1878.

The safety-test was complied with by Mr. R. T. Hare. Time, 26 seconds.

I.—*Rapidity with accuracy.*

As a magazine-gun, 24 shots were fired, of which 20 struck the target; 6 cartridges remained in the magazine. The breech-block caught once, but was soon started.

As a single-loader, 31 shots were fired, of which 24 struck the target.

II.—*Rapidity at will.*

As a magazine-gun, 18 shots were fired; 1 cartridge remained in the magazine.

As a single-loader, 21 shots were fired; 1 cartridge remained in the chamber.

III.—*Endurance.*

Some catching of the breech-block occurred during this test.

IV.—*Defective cartridges.*

Great escape of gas at each round.

After first fire the receiver was found burst through just opposite the extractor.

V.—*Dust.*

Magazine did not feed properly at commencement of firing.

Breech-block worked hard. Shells could not be extracted without great difficulty.

Gun worked so unsatisfactorily that the Board discontinued the test before the second dusting.

The recorder was directed to notify the owners.

Gun withdrawn.

Russel Magazine for Hotchkiss Gun.

(Wooden model.)

This magazine is intended to provide a continuous supply of cartridges by the insertion of tin boxes containing 5 cartridges each in the channel A in the butt-stock. Plate XIX.

Each box contains a spring, B, which assists gravity in producing a rapid descent of the cartridges. The feeding apparatus, Fig. 2, is a combination of a ratchet and spiral spring. To the inside of the magazine-tube springs C are secured by solder. The opposite side of the tube is slotted for the reception of the sliding-bar or ratchet D, to which springs are attached in a similar manner. Pivoted to the bar is an arm E, Figs. 1 and 3, at the front of which is a projection, F, over which hooks a corresponding projection, G, on the breech-bolt. When the breech-bolt is withdrawn the arm and ratchet are compelled to move with it until the projection F rides under a beveled shoulder at the end of the groove in which it slides, when the arm is released and the magazine-spring returns it and the ratchet to their first position. It will thus be seen that the ratchet is moved automatically, being drawn back by the bolt and returned by the magazine-spring. When the ratchet is withdrawn each spring connected with it passes behind the head of the cartridge next in rear of it; when returned the cartidges are carried forward, the 2d replacing the 1st, which will have entered the chamber, the 3d the 2d, and so on.

This magazine carries 9 cartridges.

Shots.

Rust.		
Shots.	Miss fires.	Remarks.
		Breech-system worked wit difficulty.
		Lever could not be close when last cartridge wa fed from magazine; other wise gun worked fairly.
		Gun worked well
		Gun worked well
		Bolt pulled out
		Magazine cut-off rusted i its seat; otherwise gu worked well.
		Gun worked well

Synopsis of additional supplementary tests for ascertaining the liability of accidental explosions in magazines.

The tests were conducted for the purpose of ascertaining:

I. The liability of explosion of cartridges in magazine resulting from trotting or double-quick motion.

II. The liability of explosion of cartridges in magazine resulting from the manual exercise (order arms) or accidental dropping of the piece.

III. The liability of explosion of cartridges in magazine due to inertia of the column of cartridges when the piece is fired and when the magazine loaded is held in reserve.

FIRST TEST.

The test applied to ascertain the effect due to a trotting or double-quick motion.

A cal. 0''.58 rifle, bored out to cal. 0''.63 and used as an artificial magazine, is represented at Fig. 5, Plate XXI. In the bottom of the barrel is an ordinary spiral magazine-spring with follower, the cartridges placed upon the spring in same manner as in ordinary magazine fire-arms.

The weight of the artificial magazine or gun was 7½ pounds. The housing of the magazine is lifted up in its frame by a peculiar crank-motion communicated to it by means of a leather belt. The housing falls of its own weight a distance of 5¾ inches, 59 strokes per minute. Weight of artificial magazine and housing, 19 pounds.

The cartridges in the test were jolted in magazine for one hour, both with and without the spring in the magazine; no explosion resulted. The bottom bullet was flattened considerably, as shown by line *a a*, Fig. 1, Plate XXI, and the remaining bullets flattened proportionally to weight of column resting on them.

The substitution of sharp-pointed steel plug for bottom bullet (see Fig. 2), and the same jolting test as above applied, was attended with same result, except that an indent in bottom cartridge was made by point of plug similar in appearance and quite as deep as the indent made by firing-pin on a dummy cartridge; no explosion resulted.

SECOND TEST.

The magazine weighted 9 pounds, and dropped 20 feet as specified; no explosion resulted when the cartridges with bullets were used; the bullets were slightly flattened, the bottom bullet of column to the line *b b*, Fig. 1.

Substituting steel-pointed plug with the spring in magazine for the bottom cartridge, explosion resulted, and the dummy shell with pointed plug was altered in shape from Fig. 2 to Fig. 3. The bottom cartridge-shell was melted, and its bullet found in the magazine badly upset, as shown at Fig. 4. All other cartridges were lost—either exploded or shot out of magazine.

THIRD TEST.

With the Remington arm (magazine loaded and cut off), spring in front of column of nine cartridges, no explosion resulted from inertia due to shock of firing 100 cartridges; bottom bullet slightly flattened.

HOTCHKISS GUN.

(Magazine loaded and cut off.)

Spring in rear of column of five cartridges, no explosion resulted from firing 100 cartridges; bottom bullet very slightly flattened.

The line *c c*, Fig. 1, shows the degree of necessary compression of point of bullet in order to prevent its bearing upon the priming space in center of cartridge shell; 140 pounds dead weight, or dropping the cartridge sixteen times through a height its own length, the point of bullet striking on hard surface, expresses the force necessary to reach this limit of safety.

TARGET RECORD OF AMMUNITION UPSET IN MAGAZINE-TUBE, AT 500 YARDS.

Frankford arsenal service-rifle cartridges.

1.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	″	″	″	″	″	″	″	″
1	51	....	36	....	36.9	......	35.⅔	......
2	4	....	....	2	......	10.1	......	2⅓
3	25	....	....	4	10.9	......	......	4⅓
4	10	....	....	6	......	4.1	......	6⅓
5	....	1	....	6	......	15.1	......	6⅓
6	4	....	8	....	......	10.1	7⅔	......
7	2	....	....	2	......	12.1	......	2⅓
8	16	....	....	3	1.9	......	......	3⅓
9	16	....	....	18	1.9	......	......	18⅓
10	Missed the target.							
	128	1	44	41	51.6	51.5	43⅓	43⅓
C. I.	14.1	....	⅓	....	M. H. D. 9.63		M. A. D. 15	
					M. V. D. 11.5			

2.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	″	″	″	″	″	″	″	″
1	16	....	6	....	4.5	......	......	1.3
2	10	....	....	27	......	1.5	......	34.3
3	29	....	....	11	17.5	......	......	18.3
4	25	....	11	....	13.5	......	3.7	......
5	12	....	4	....	.5	......	......	3.3
6	25	....	....	11	13.5	......	......	18.3
7	14	....	31	....	2.5	......	23.7	......
8	....	10	6	....	......	21.5	......	1.3
9	8	....	28	....	......	3.5	20.7	......
10	....	14	36	....	......	25.5	28.7	......
	139	24	122	49	52	52	76.8	76.8
C. I.	11.5	....	7.3	....	M. H. D. 15.4		M. A. D. 18.6	
					M. V. D. 10.4			

3.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	″	″	″	″	″	″	″	″
1	16	....	....	10	4.8	......	......	......
2	....	....	24	....	......	11.2	......	......
3	14	....	7	....	2.8	......	......	......
4	25	....	17	....	13.8	......	......	......
5	9	....	....	....	......	2.2	......	......
6	....	....	2	....	......	11.2	......	......
7	21	....	....	13	9.8	......	......	......
8	17	....	10	....	5.8	......	......	......
9	29	....	....	1	17.8	......	......	......
10	....	19	....	7	......	30.2	......	......
	131	19	60	31	54.8	54.8	46.4	46.4
C. I.	11.2	....	2.9	....	M. H. D. 9.3		M. A. D. 14.4	
					M. V. D. 11			

Winchester Repeating Arms Companies service-rifle cartridges.

1.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	″	″	″	″	″	″	″	″
1	....	1	13	....	7.1	......	......	3.2
2	12	....	....	10	20.1	......	......	26.2
3	....	17	14	....	......	8.9	......	2.2
4	....	18	13	....	......	9.9	......	3.2
5	23	....	23	....	31.1	......	6.8	......
6	....	10	....	....	......	1.9	......	16.2
7	11	....	24	....	19.1	......	7.8	......
8	....	6	16	....	2.1	......	......	.2
9	....	31	34	....	......	22.9	17.8	......
10	....	44	35	....	......	35.9	18.8	......
	46	127	232	41	79.5	79.5	51.2	51.2
C. I.	....	8.1	16.2	....	M. H. D. 10.2		M. A. D. 19	
					M. V. D. 15.9			

2.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	″	″	″	″	″	″	″	″
1	13	....	13	....	25.1	......	......	5.6
2	....	16	13	....	......	3.9	......	5.6
3	....	18	2	....	......	5.9	......	16.6
4	3	....	6	....	15.1	......	......	12.6
5	1	....	8	....	13.1	......	......	10.6
6	....	61	40	....	......	48.9	21.4	......
7	7	....	6	....	19.1	......	......	12.6
8	....	....	15	....	12.1	......	......	3.6
9	....	39	56	....	......	26.9	37.4	......
10	....	11	27	....	1.1	......	8.4	......
	24	145	18.6	....	85.6	85.6	67.2	67.2
C. I.	....	12.1	18.6	....	M. H. D. 13.5		M. A. D. 21.8	
					M. V. D. 17.2			

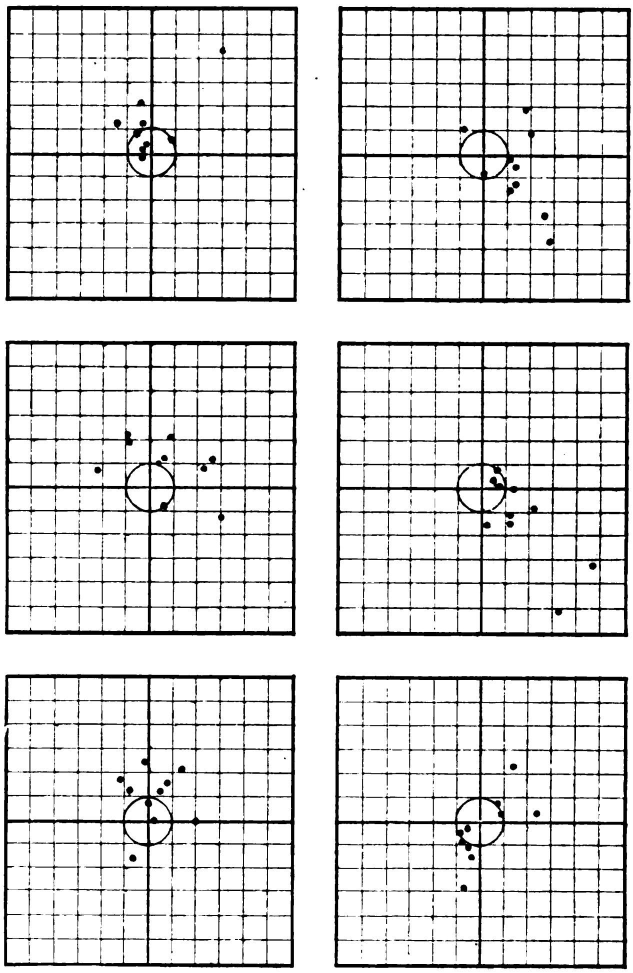
3.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	″	″	″	″	″	″	″	″
1	28	....	18	....	32	......	12.7	......
2	....	13	....	7	......	9	......	12.3
3	....	3	....	7	1	......	......	12.3
4	....	6	8	....	......	2	2.7	......
5	....	8	10	....	......	4	4.7	......
6	2	....	8	....	6	......	2.7	......
7	4	....	29	....	8	......	23.7	......
8	....	17	....	6	......	13	......	11.3
9	8	....	9	....	12	......	3.7	......
10	....	35	....	9	......	31	......	14.3
	42	82	82	29	59	59	50.2	50.2
C. I.	....	4	5.1	....	M. H. D. 10		M. A. D. 15.5	
					M. V. D. 11.8			

PLOTTED TARGETS.

[Scale ½ inch to the foot.]

Frankford arsenal service-rifle cartridges.	*Winchester Repeating Arms Companies service-rifle cartridges.*



Point of sight: Center of target.
Wind: Stiff breeze.
Direction: Left and front.
How fired: Muzzle rest.
By whom fired: R. T. Hare.
Officer in charge: John E. Greer, first lieutenant of ordnance, United States Army.

TARGET RECORD OF AMMUNITION UPSET IN MAGAZINE-TUBE, AT 500 YARDS.

Union Metallic Cartridge Company's service-rifle cartridges.

1.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	"	"	"	"	"	"	"	"
1	13	....	35	....	......	7.8	25.3	......
2	8	....	13	....	......	12.8	3.3	......
3	41	....	14	....	20.2	......	4.3	......
4	25	....	....	....	4.2	......	......	9.7
5	19	....	....	6	......	1.8	......	15.7
6	25	....	11	....	4.2	......	1.3	......
7	38	....	7	....	17.2	......	......	2.7
8	12	....	....	6	......	8.8	......	15.7
9	7	....	18	....	......	13.8	8.3	......
10	20	....	11	....	......	.8	1.3	......
	208	....	109	12	45.8	45.8	43.8	43.8
C. I.	20.8	....	9.7	....	M. H. D. 8.8		M. A. D. 12.7	
					M. V. D. 9.2			

2.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	"	"	"	"	"	"	"	"
1	22	....	25	....	......	2.9	15.2	......
2	25	....	10	....	.1	......	.2	......
3	23	....	17	....	......	1.9	7.2	......
4	18	....	....	14	......	6.9	......	23.8
5	32	....	12	....	7.1	......	2.2	......
6	23	....	27	....	......	1.9	17.2	......
7	33	....	....	15	8.1	......	......	24.8
8	25	....	8	....	.1	......	......	1.8
9	42	....	20	....	17.1	......	10.2	......
10	6	....	13	....	......	18.9	3.2	......
	249	....	132	29	32.5	32.5	56.4	50.4
C. I.	24.9	....	10.3	....	M. H. D. 13.5		M. A. D. 21.8	
					M. V. D. 17.2			

3.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	"	"	"	"	"	"	"	"
1	8	....	....	10	9.5	......	......	11.8
2	15	....	6	....	16.5	......	4.2	......
3	8	....	11	....	9.5	......	9.2	......
4	25	....	4	....	26.5	......	2.2	......
5	1	....	7	....	2.5	......	5.2	......
6	Mis	sed	tar	get.				
7	Mis	sed	tar	get.				
8	....	66	....	7	......	64.5	......	8.8
9	Mis	sed	tar	get.				
10	Mis	sed	tar	get.				
	57	66	28	17	64.5	64.5	20.8	20.6
C. I.	....	1.5	1.8	....	M. H. D. 4.1		M. A. D. 22.	
					M. V. D. 21.6			

United States Cartridge Company's service-rifle cartridges.

1.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	"	"	"	"	"	"	"	"
1	19	....	57	....	......	1.3	40.2	......
2	37	....	20	....	16.7	......	3.2	......
3	33	....	....	1	12.7	......	......	17.8
4	29	....	5	....	8.7	......	......	11.8
5	....	1	11	....	......	21.3	......	5.8
6	7	....	....	7	......	13.3	......	23.8
7	21	....	20	....	.7	......	3.2	......
8	22	....	36	....	1.7	......	19.2	......
9	12	....	1	....	......	8.3	......	15.8
10	24	....	26	3.7	......	......	9.2	......
	204	1	176	8	44.2	44.2	75.0	75.0
C. I.	20.3	....	16.8	....	M. H. D. 15.		M. A. D. 17.4	
					M. V. D. 8.8			

2.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	"	"	"	"	"	"	"	"
1	13	....	....	22	9.3	......	......	35.3
2	....	8	27	....	......	11.7	13.7	......
3	12	....	31	....	8.3	......	17.7	......
4	27	....	23	....	23.3	......	9.7	......
5	....	25	7	....	......	28.7	......	6.3
6	....	....	17	....	......	3.7	3.7	......
7	7	....	10	....	3.3	......	......	3.3
8	Mis	sed	tar	get.				
9	Mis	sed	tar	get.				
10	Mis	sed	tar	get.				
	59	33	115	22	44.2	44.1	44.8	44.9
C. I.	3.7	....	13.3	....	M. H. D. 12.7		M. A. D. 17.9	
					M. V. D. 12.6			

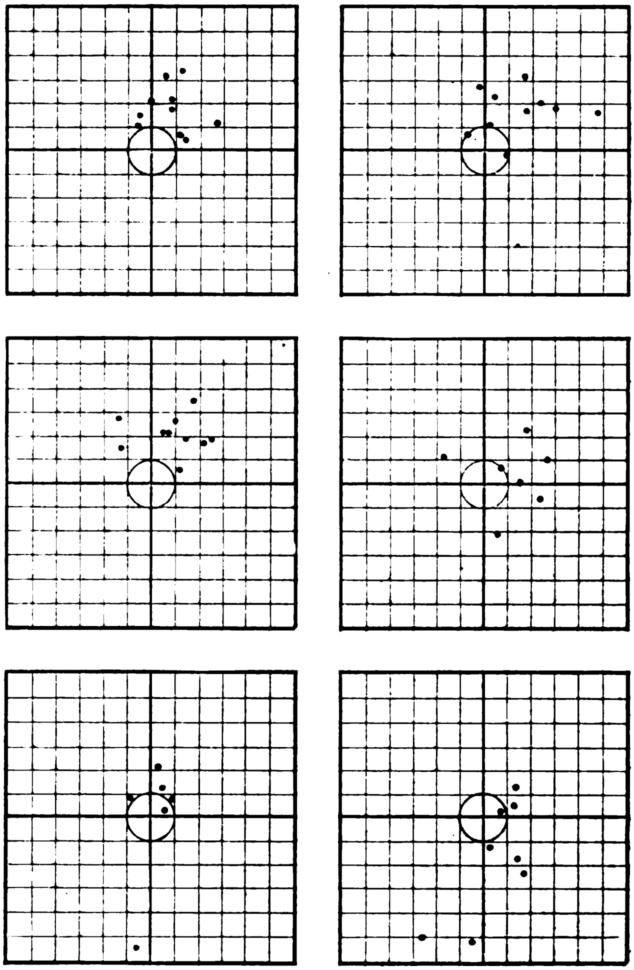
3.

No.	A.	B.	R.	L.	A.	B.	R.	L.
	"	"	"	"	"	"	"	"
1	Mis	sed	tar	get.				
2	....	21	18	....	......	.8	12.5	......
3	15	....	15	....	35.2	......	9.5	......
4	....	14	2	....	6.2	......	......	3.5
5	1	....	10	....	21.2	......	4.5	......
6	....	60	....	34	......	39.8	......	39.5
7	6	....	15	....	26.2	......	9.5	......
8	....	28	23	....	......	7.8	17.5	......
9	Mis	sed	tar	get.				
10	....	61	....	5	......	40.8	......	10.5
	22	184	83	39	88.8	89.2	53.5	53.5
C. I.	....	20.2	5.5	....	M. H. D. 13.4		M. A. D. 25.9	
					M. V. D. 22.2			

PLOTTED TARGETS.

(Scale ⅛ inch to the foot.)

Union Metallic Cartridge Company's service-rifle cartridge.	*United States Cartridge Company's service-rifle cartridge.*

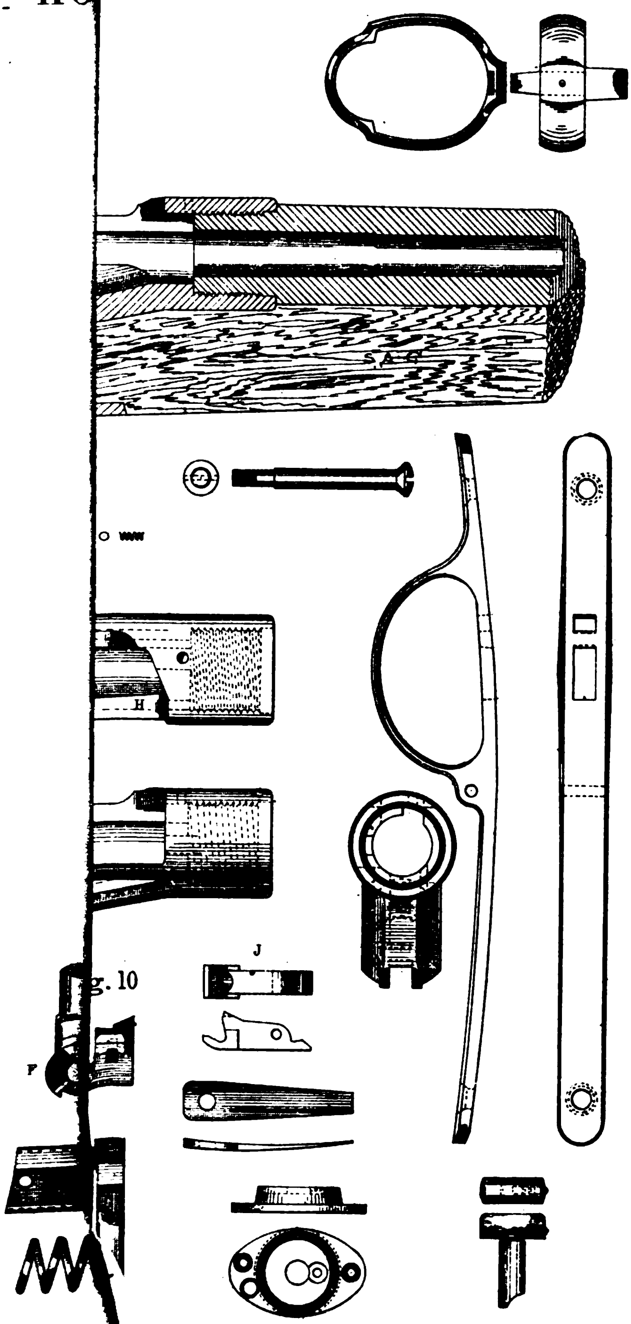


Point of sight: Center of target.
Wind: Stiff breeze.
Direction: Left and front.
How fired: Muzzle rest.
By whom fired: R. T. Hare.
Officer in charge: John E. Greer, first lieutenant of ordnance, United States Army.

INDEX OF APPENDIX T.

HO

PLATE I.



Accompanying Appendix T, 1878

INDEX.